ADVANCED MECHANIZATION OPERATIONS FOR GROCERY WAREHOUSES

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PREFACE

This study of advanced mechanization of grocery warehouse operations is part of a broad program aimed at reducing the cost of marketing farm products. One phase of this research is the development of methods for increasing efficiency of food wholesaling.

Increased efficiency results in better service or lower marketing costs and savings will be reflected in lower consumer prices, in increased producer returns, or in both.

Special acknowlegment is due Management of Alpha Beta Acme Markets, Inc., La Habra, Calif.; John Deere, Dubuque, Iowa; Dean Foods Co., Belvidere, Ill.; Eastman Kodak Co., Rochester, N.Y.; The Great Atlanta and Pacific Tea Co., New York, N.Y.; The Sperry and Hutchinson Co., Hillside, Ill.; and others who cooperated in this study by allowing researchers to study their operations and by providing cost data. Equipment manufacturers, who provided data and contacts, and the 12 food distribution and warehouse operations specialists, who critically evaluated an earlier draft of this report deserve special acknowledgment.

This study initiated under the general direction of R. W. Hoecker (now retired), Assistant Division Director, and John C. Bouma, former Investigations Leader in the Marketing Facilities Development Branch, (currently Chief of the Market Operations Research Laboratory, Agricultural Marketing Research Institute, Agricultural Research Service) was completed under the general direction of K. H. Brasfield, Chief, Food Distribution Research Laboratory, Agricultural Marketing Research Institute, Agricultural Research Service.

The study was conducted under contract with A. T. Kearney, Inc., Chicago, Ill. The contract was administered by Jack L. Runyan, marketing specialist, Food Distribution Research Laboratory, Agricultural Marketing Research Institute, Agricultural Research Service.

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ADVANCED MECHANIZATION OPERATIONS FOR GROCERY WAREHOUSES

An Evaluation and Projection

By Jack L. Runyan and Arthur E. Nyquist 1/

SUMMARY

This study showed that advanced mechanized operations were not a good investment alternative as a hypothetical conventional grocery warehouse operation (based on data obtained from secondary research sources). Although labor productivity for the advanced mechanized operations ranged from 106 to 137 cases per man-hour as compared with 107 cases per man-hour for a hypothetical conventional operation, the estimated return on investment in nonconventional equipment for the advanced mechanized operations only ranged from 3.0 to 7.5 percent. Total warehouse labor costs for the advanced mechanized warehouse operations ranged from $44.07 per 1,000 cases to $55.31 per 1,000 cases compared with $53.30 per 1,000 cases for the hypothetical conventional operations.

Mechanized warehouse operations could not be recommended over actual conventional grocery warehouse operations similar to the hypothetical operation. However, since many actual conventional grocery warehouse operations do not have productivity approximating the productivity of the hypothetical operation, a mechanized operation in 1980 will probably include storage-retrieval machines to perform the put-away and replenishment functions and computerized selection to perform the order-selection function. Also depalletizers and conveyors will move cases of products from the storage area to the selection area. The facility to house the mechanized operation will consist of high-level storage (probably over 95 feet high).

The following set of criteria were recommended for making decisions relative to advanced mechanized warehouse operations: (1) Review of present operations; (2) establish return on investment goals; (3) develop future plans; (4) determine operational requirements for the future; (5) make preliminary evaluations of the alternative systems; (6) list available equipment; (7) update cost trends; (8) select alternatives; (9) test alternatives; (10) simulate operations; and (11) make the decision.

1/ Respectively, marketing specialist, Food Distribution Research Laboratory, Agricultural Marketing Research Institute, Agricultural Research Service, and principal, A. T. Kearney, Inc.

INTRODUCTION

This report focuses on analyzing developments in the mechanization of grocery warehouse operations. Mechanization of warehouse operations is not to be equated with automation of warehouse operations. Many tasks in warehouse operations can be made more efficient by supplementing manual handling with improved mechanical handling. Supplementing manual handling with improved mechanical handling, if done properly, makes maximum use of both human and mechanical resources. The term "mechanization of warehouse operations" refers to the supplementing of manual handling with mechanical handling. Automation of warehouse operations refers to a complete replacement of manual handling with mechanical handling and is beyond the scope of this study.

OBJECTIVES AND APPROACH

The general objectives of this study were as follows:

- To provide research results to help managers of grocery warehouses plan their future operations.
- To offer manufacturers of warehousing equipment guidelines for their future developmental projects.
- To determine time and cost standards for conventional and advanced mechanized operations in grocery warehouses.
- To determine trends in food distribution warehouse operations.
- To develop recommendations for the advanced mechanized grocery warehouse operation for 1980, isolating design criteria, and performance characteristics.

To accomplish the objectives of the study the following approaches were taken:

1. Secondary sources were utilized to develop time and cost information for a hypothetical conventional grocery warehouse to serve as a benchmark or basis for comparison.

2. Seven warehouse operations (four food and three nonfood warehouses) using advanced mechanized operations were selected for analysis. The analysis of these seven advanced mechanized operations consisted of the following:

- To observe the operations in order to determine the current "state-of-the-art."
- To measure the specific capabilities of each operation in terms of cost and productivity performance as well as return on investment.
- To evaluate intangible considerations such as reliability, safety, loss and damage, and obsolesence.

3. Grocery warehouse managers, equipment manufacturers, and others with knowledge of the food distribution industry were contacted to determine trends in grocery warehouse operations.

4. The data accumulated for the advanced mechanized warehouse operations were compared with the "benchmark" data. The data comparison and the knowledge contributed by grocery warehouse managers, equipment manufacturers, and others were used to develop the recommendations for the advanced mechanized food distribution warehouse operations for 1980.

PRODUCTIVITY AND COSTS FOR A HYPOTHETICAL CONVENTIONAL GROCERY WAREHOUSE OPERATION

The purpose of this section is to develop productivity and cost data for a hypothetical conventional grocery warehouse operation that will handle 24 million cases of products per year. The data developed are the basis for comparison with the advanced mechanized operations.

Direct Warehouse Labor

In grocery warehouses, the direct handling functions performed are receiving, selecting, and shipping. These functions will continue to be performed regardless of the level of mechanization. The equipment and direct labor costs for performing these functions plus building and indirect labor costs compose warehouse operating costs. As an average percentage of total warehouse operating costs, labor accounts for 70 percent, building accounts for 20 percent, and equipment accounts for 10 percent (5).2/

Receiving

The receiving function includes all physical handling of inbound merchandise to the point of readiness for order selection. Indirect labor consists of the checking of inbound merchandise and the handling of receiving documents.

Merchandise is transported from suppliers to grocery warehouses via rail and truck. Approximately 30 percent of the inbound merchandise is transported via rail and approximately 70 percent via truck.

Railcar Unloading

The methods and equipment used for unloading railcars depend on the method used by suppliers for loading railcars. For example, if suppliers place unitized loads (pallets or slip sheets) of products in the railcar, the cars are unloaded with forklift trucks or pallet jacks. However, if suppliers

2/ Underscored numbers in parentheses refer to Literature Cited, page 54.

do not use the unitized loading method, the cars are unloaded by manual placing of products onto pallets and removing the loaded pallets either by pallet jacks or by forklift trucks. Approximately 40 percent of railcar unloading is unitized.

Bouma reported overall railcar unloading productivity amounting to 462 cases per man-hour could be achieved with one man to palletize and move loaded pallets out of a railcar (2).

Truck Unloading

The methods and equipment used for truck unloading also depend on the method used by suppliers for loading the trucks. However, unlike railcar deliveries, truck drivers usually move the products from the delivery vehicle to the warehouse receiving dock. When inbound truckloads are not unitized, the truck drivers place the products on pallets in the stacking pattern specified by the warehouse management. After the product has been removed from the truck, warehouse employees (usually forklift operators) put the pallet loads in predesignated storage locations. When products are back-hauled (transported from suppliers to the warehouse via trucks owned by the warehouse), warehouse employees usually perform the entire unloading task.

Since drivers remove most of the inbound truck shipments from delivery vehicles, mechanization would not change productivity of warehouse employees. Therefore, truck unloading was not considered to be a major factor.

Put Away and Replenishment

Put away and replenishment consists of moving unit loads from the receiving dock and placing them in storage, and moving unit loads from storage and placing them in the order-selection area (slots). Put away and replenishment are usually performed by forklift operators.

Runyan reported that productivity for putting away and replenishing amounting to 639 cases per man-hour could be achieved in conventional grocery warehouses (8).

Order Selecting

The order selecting includes selectors physically handling merchandise from the selection slots to the shipment staging area located on the shipping dock. Also order selectors mark cases, apply labels for identification, and check cases for accuracy if checking is part of the order selector's job. Order checking productivity, if performed by someone other than the order selector, is included in indirect labor.

Order selecting in the repack area (the area where less than full case quantities are packed into containers for easier handling) was not included in this study because handling procedures are currently the same in both conventional and advanced mechanized operations.

Concurrently in conventional grocery warehouse operations there are four order-selecting methods used as follows:

1. Electric pallet jacks and pallets—selector places products on pallets and transports them by electrically powered jacks.

2. Train—selector places products onto one of two or more four-wheel selector trucks or mobile carts which are pulled by an electrical or gas-powered tugger.

3. Towline—selector places products on four-wheel selector trucks or mobile carts and manually moves them during selecting. When loaded, the mobile carts are hooked onto a towline that moves the loaded vehicle to the shipping dock.

4. Manual—selector places products on four-wheel selector trucks or mobile carts that are pushed by selectors throughout the entire selection function.

The towline and manual methods are not widely used and, therefore, will not be used in the hypothetical operation.

The average productivity for the two order-selection methods amounted to 222 cases per man-hour (11).

Shipping

The shipping function, as used in this study, is delivery truck loading at the warehouse. Truck loading includes removing materials returned to the warehouse from the retail store, loading outbound products, and placing of dividers, nets, or dunnage around orders. Truck loading excludes order checking.

The two methods most widely used for loading products are as follows:

1. Palletized—products are handled as unit loads and are loaded and unloaded with pallet jacks or forklift trucks.

2. Carts—products are handled as unit loads and the carts are loaded and unloaded by manually pushing them.

The average productivity for delivery truck loading by the two methods amounted to 1,584 cases per man-hour (11).

Overall Direct Warehouse Labor Productivity

The direct labor productivities for receiving, selecting, and shipping functions as well as overall direct labor productivity are shown in table 1. These productivities represent part of the basis for comparison with the advanced mechanized operations.

TABLE 1.—Direct labor productivity for receiving, selecting and loading, and overall direct labor productivity in the hypothetical conventional warehouse operations

Direct labor productivity	Cases per man-hour	Overall or average direct labor productivity cases per man-hour 1/
Receiving	----	452
Railcar unloading	462	----
Truck unloading	----	----
Put away and replenish	639	----
Order selecting	----	222
Pallets—electric pallet jack	202	----
Mobile carts—train	242	----
Loading	----	1,584
Pallets	1,500	----
Mobile carts	1,667	----
Overall direct labor productivity	----	136

1/ Calculated as follows: (1) Assume 1,000 cases received, (2) 300 (30 percent of total) cases received ÷ 462 cases per man-hour = 0.65 man-hour for railcar unloading, (3) 1,000 cases received ÷ 639 cases per man-hour = 1.56 man-hours for putting away and replenishing, (4) 1,000 cases received ÷ 2.21 man-hours (65 man-hours for railcar unloading + 1.56 man-hours for putting away and replenishing) = 452 cases per man-hour productivity for overall receiving.

Indirect Warehouse Labor

Indirect warehouse labor is nontouch labor (no actual handling of products) and includes the control operations necessary for the functioning of the warehouse. Included as indirect warehouse labor are checkers and supervisors. Checkers count and verify orders received or shipped either by

item or piece count. Supervisors plan work, direct and train personnel, and select equipment. Not included in this classification are equipment maintenance and other support labor categories which will be discussed later.

The productivity for each category and overall indirect labor is shown in table 2. Indirect labor productivity is related to direct labor productivity and to the number of people falling into this category.

TABLE 2.—Indirect warehouse labor productivity in the hypothetical conventional warehouse operation 1/

Categories	Cases per man-hour
Inbound checking	1,672
Outbound checking	1,149
Supervision	1,856
Overall indirect 2/	496

1/ Sources: (2, 4, 6, 7, 10) and calculations.
2/ See footnote 1, table 1, for method of calculations.

Summary of Direct and Indirect Labor Productivity

Overall warehouse direct and indirect labor productivity amounted to 107 cases per man-hour (table 3). These are the productivity figures that will be used as a basis for comparison with the advanced mechanized warehouse operations.

TABLE 3.—Summary of direct and indirect labor productivity and overall labor productivity in the hypothetical conventional warehouse operations 1/

Labor classification	Cases per man-hour
Direct	136
Indirect	496
Throughput 2/	107

1/ Source: Tables 4 and 5 and calculations.
2/ See footnote 1, table 1, for method of calculations.

Labor, Building, and Equipment Costs

The direct and indirect labor productivity discussions did not include costs. Comparing costs of operations is very important because occasionally a change in operations (new equipment or method) may increase productivity, but the cost of making the change may be prohibitive. The relevant costs for the analysis are labor, building, and equipment costs.

Labor Costs

Hourly labor costs by job classification for 1960, 1965, and 1970 are shown in table 4. The costs are based on a national average and subject to variations between geographical regions. For example, wage rates in highly populated large industrial regions are much higher than those in less populated rural regions.

TABLE 4.—Average wage trends for materials handling and delivery job classification 1/

Job classification	Wages per hour			Percentage increases		
	1960	1965	1970	1960 to 1970	1960 to 1965	1965 to 1970
	---------Dollars-------			-------Percent-----------		
Power truck operators (forklift, pallet jack).	2.29	2.83	3.60	57	24	27
General material handling labor 2/.	2.09	2.55	3.32	59	22	30
City truck drivers (tractor-trailer).	2.68	3.21	4.16	55	20	30
Overall average-----	2.35	2.86	3.69	57	22	29

1/ Source: Bureau of Labor Statistics, U.S. Department of Labor, and calculations.

2/ Includes inbound and outbound order checkers.

Percentage increases in wages for the periods of 1960 to 1970, 1960 to 1965, and 1965 to 1970 are also shown in table 4. The trend indicated by the percentage changes is more important than the actual dollar changes (not shown in table 4). If the trends continue, present wage rates will increase

at an annual rate of 5.7 percent and double in the next 12.5 to 13 years. However, it was estimated that wage rates will increase at a compounded annual rate of 8 percent per year and will double in 9 years.

Building Costs

Building costs refer only to the actual cost of the structure and do not include land costs. Naturally, when management is considering new facilities it must also consider land costs. However, because land costs differ so widely and fluctuate widely in short time periods, they were not included.

Initial investment and annual fixed building costs amounted to $12 and $1.65 per square foot, respectively, (table 5). Building cost increases have followed the same trend as labor cost increases according to calculations made from data appearing in various issues of "Boeckh Building Cost Index Numbers" (1).

TABLE 5.—Warehouse building investment and annual expenses 1/

Item	Dollars per square foot
Initial investment in the structure---	12.00
Annual fixed costs:	
Depreciation or lease expense-------	1.20
Building operating overhead 2/------	.45
Total building cost----------------	1.65

1/ Source: (1, 2, 8, 9).
2/ Includes maintenance, utilities, taxes, and miscellaneous facility costs.

Equipment Costs

Costs for equipment used in hypothetical conventional warehouse operations refer to costs for actual materials handling equipment and other equipment necessary to perform the warehousing function. As shown in table 6, warehouse equipment costs amounted to $0.0090 per case.

As was the case with building costs, increases in initial costs for materials handling equipment have followed the same general trend as increases in labor costs.

TABLE 6.—Equipment costs in a conventional grocery warehouse operation 1/

Warehouse equipment cost 2/ (per cases handled)	Dollars
Equipment operating cost----------	0.0036
Equipment investment cost---------	.0054
Total---------------------------	.0090

1/ Sources: (2, 9, 11) and calculations.
2/ Includes costs of pallet racks, materials handling, communications, and warehouse-related data processing equipment.

Summary of Productivity and Costs

The productivity and cost data are summarized in table 7. These productivity and cost data represent the benchmark data used for comparison of the conventional operations with advanced mechanized warehouse operations.

TABLE 7.—Summary of productivity and cost benchmarks for the hypothetical conventional grocery warehousing operations

Function or cost element	Cases per man-hour	Dollars
Productivity:		
Receiving:		
Rail unloading-----------------	462	---
Truck unloading----------------	---	---
Put away and replenish----------	639	---
Overall receiving---------------	452	---
Order selection-----------------	222	---
Truck loading-------------------	1,584	---
Overall warehouse direct labor---	136	---
Overall warehouse indirect labor-	496	---
Throughput----------------------	107	---
Costs:		
Building--initial investment (per square foot).	---	12.00
Total annual fixed cost (per square foot).	---	1.65
Equipment--warehouse cost (per case handled).	---	.0090

PRODUCTIVITY AND COSTS FOR ADVANCED MECHANIZED GROCERY WAREHOUSE OPERATIONS

The most reliable comparisons can be made only when total systems are matched. In other words, one piece of an advanced mechanized system should not be compared with the comparable portion of a conventional system without considering the related functions. For example, the case selection rates in a given mechanized facility may be twice that of a conventional warehouse, but the additional operations required to enable the high selection rate may negate some of the selection savings.

Thus, in this study an effort has been made to compare warehousing operations on a total systems basis to avoid any discrepancies caused by differences in the classification of warehouse functions from one company to another.

Seven advanced mechanized warehouse operations were studied for this analysis. Three of the operations studied were handling groceries, one was handling frozen foods, and the others were handling nonfoods. All of the operations furnished a broad picture of warehouse mechanization and the current "state-of-the-art," and provided insight for potential developments in grocery warehouse operations.

The seven mechanized warehouse operations studied may be summarized as follows: (1) Mechanized case take away from the point of selection with manual order sorting; (2) mechanized case take away from the point of selection with mechanized order sorting; (3) mechanized selector transfer; (4) mechanized storage and retrieval of unit loads; (5) manual selection from pallet loads cycling between the storage and selection areas by storage-retrieval machines; (6) reserve storage by storage-retrieval machine with subsequent transfer to gravity-fed flow racks, and manual selection onto guided tow-tractor train; and (7) mechanized selection and take away from point of selection and sorting of orders.

Mechanized Case Take Away From Point of Selection

Manual Order Sorting

In this nonfood distribution warehouse operation, cases are delivered to the warehouse by railcar and truck. Truck drivers and warehouse personnel unload and palletize the inbound shipments. The pallet loads are placed on four-wheel carts and pulled by towline to the reserve storage area where forklift trucks remove the pallet loads from the four-wheel carts and place them into reserve storage. Later the forklift trucks transfer the pallet loads from the reserve storage area to their assigned slots in the order selection area.

The order selection area is divided into two levels on a mezzanine elevated above the warehouse floor. Four conveyor selection lines (two per

level), each serving a different group of items, are used for selecting orders. Each selection line is U-shaped and 550 feet long; therefore, a selector walks a distance of 1,100 feet in one pass through a selection line.

Using a printed store order as their picking list, the order selectors manually remove the cases of products from the selection slots and place them on the conveyors (fig. 1). A large amount of time is saved, because cases can be randomly placed on the conveyors instead of positioned in pallet loads or on carts as in conventional selection. Each order selector picks approximately one-fourth of the store's total order. Batch selection was not used in this operation due to the absence of automatic order sorting equipment and to the order selection rates being too fast for manual sorting after the four conveyor lines have been merged.

A console operator is positioned at a central control station (fig. 2) where the four selection line conveyors merge (fig. 3) to form three conveyors that lead to the truck dock. These three conveyors are subsequently divided to form six separate declining conveyors (fig. 4) that lead to the six shipping doors. Truck loading (fig. 5) and the changeover from loaded trucks to empty ones become a steady and continuous process as a result of the six declining conveyors.

The pallet accumulation system, an additional feature of this operation, consists of a chain-tow that removes empty pallets from the selection areas and an accumulator that automatically stacks them for future use (fig. 6).

Figure 1.—Conveyor line used for order selecting.

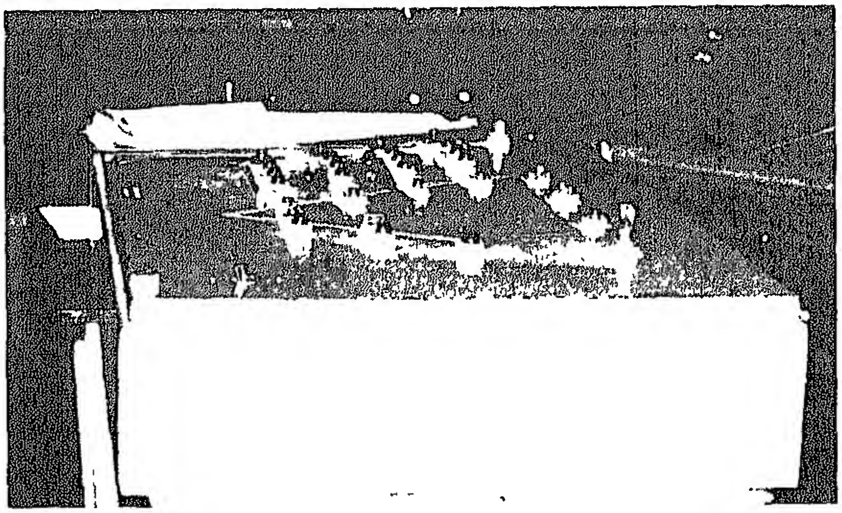

Figure 2.—Console used at central control station for merging selection line conveyors with conveyors that lead to the truck dock.

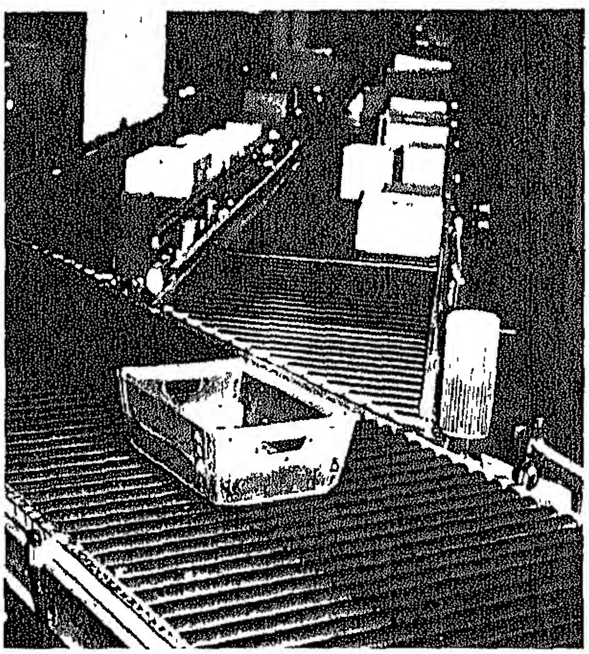

Figure 3.—Merging point of selection conveyors and conveyor leading to truck dock.

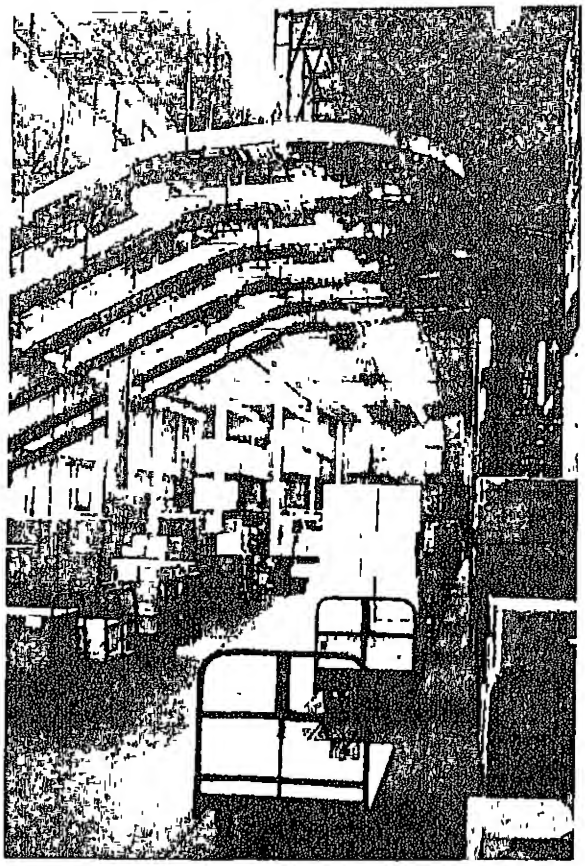

Figure 4.—Declining conveyors leading to shipping doors.

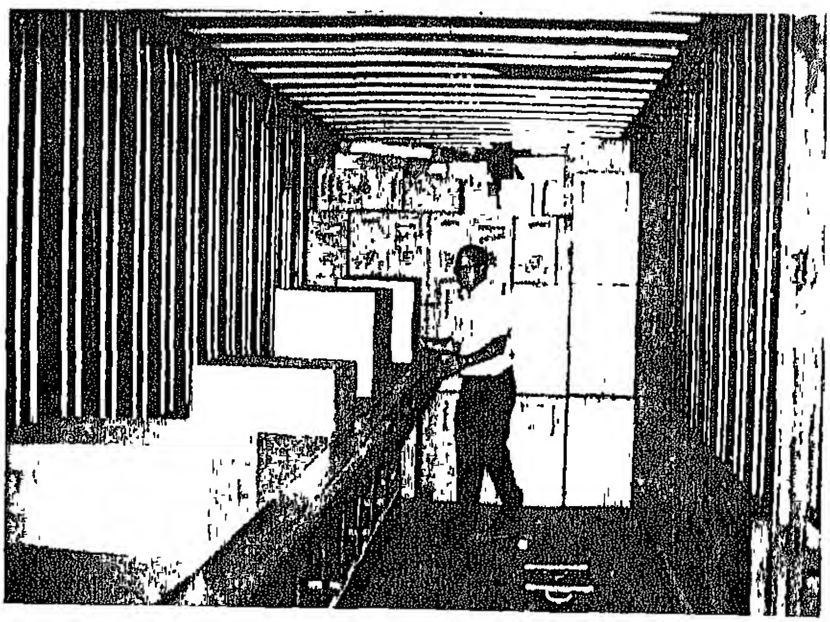

Figure 5.—Truck loading.

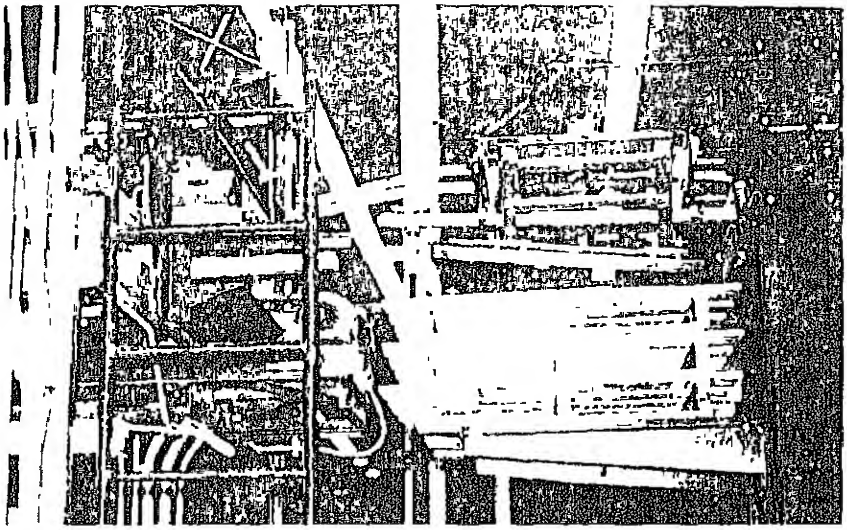

Figure 6.—Pallet accumulator.

Productivity in the receiving operation was not significantly better than for conventional warehouses. The productivity for order selection on the line was 300 cases per man-hour, but this decreased to 140 cases per man-hour when the sorting and control employees were included in the man-hour base.

This low productivity was caused by a selector having to pick for one store at a time and all selectors having to switch to another group of orders simultaneously. As many as three selectors could be detained if a given group of orders were large in a particular product area. The electronic controls had not been reliable, consequently, three extra men were required to operate as checkers, case counters, line feeders, and diverters.

Truck loading productivity for this operation was 370 cases per man-hour because of the addition of a man to handle common carrier loading. A grocery warehouse using company-owned transportation for deliveries might expect truck loading productivity to reach 480 cases per man-hour.

In addition, this operation required as much building space as a conventional operation would have required.

An approximate $750,000 investment, which included racks, conveyors, fork trucks, and electronic counters and controls, was required for this

operation. This exceeds a conventional warehouse equipment investment by approximately $330,000.

Annual maintenance costs including parts and labor (a part-time employee) amount to $8,000.

Although current productivity was lower and the equipment cost higher, significant advantages in this manual order sorting operation are as follows:

1. By replacing the electronic control with manual labor, the system has become extremely reliable.

2. Safety and damage records improved significantly and repairs are performed quickly.

3. Package labeling by a device that automatically labels cases from underneath as the cases roll by on the conveyor occurs at a single control station.

A major obstacle in this operation, however, has been its lack of flexibility. To avoid crew delays in the selection area, orders must be known in advance by at least 1 to 2 days in order to plan similarly balanced store orders. Rush orders or last minute changes are quite difficult to handle because orders are "locked in" once they are matched into a selection schedule.

Mechanized Order Sorting

In this grocery warehouse receiving was performed in the same way as in conventional warehouses. Forklift trucks take loaded pallets from the dock to reserve storage and from reserve storage to the selection lines. The reserve storage is located directly across an aisle from the rear of the selection slots, thereby reducing travel time from reserve storage to the selection slot.

There are six selection lines—three loops, each having an upper and a lower level (fig. 7) and each in a U-shaped layout. The cases are placed on a take away conveyor (fig. 8). One order selector is positioned on each side of the conveyor and walks from one end of the "U" to the other, a distance of approximately 800 feet, and selects three store orders. After a case has been selected, an "L," "O," or "X" is marked on the box indicating the symbol for the store for sortation purposes. The "L," "O," and "X" symbols were used because they are easily and rapidly written and because they are easy to distinguish from each other.

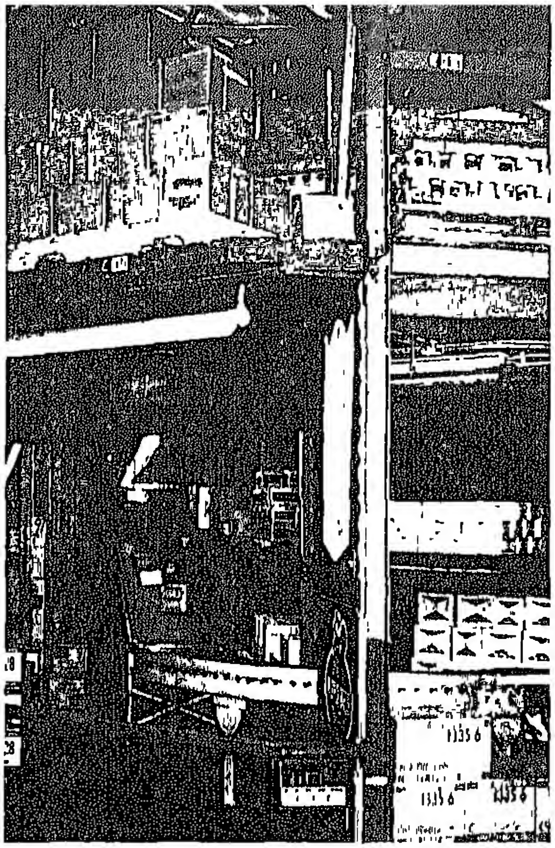

Figure 7.—Selection levels.

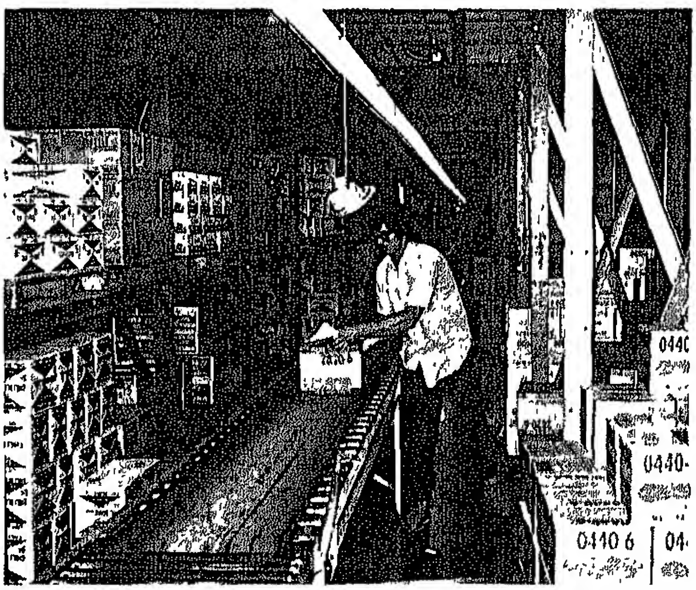

Figure 8.—Order selector placing product on conveyor.

The take-away conveyors are merged to form two parallel lines passing through two mechanical sorters (fig. 9). These lines extend into the delivery

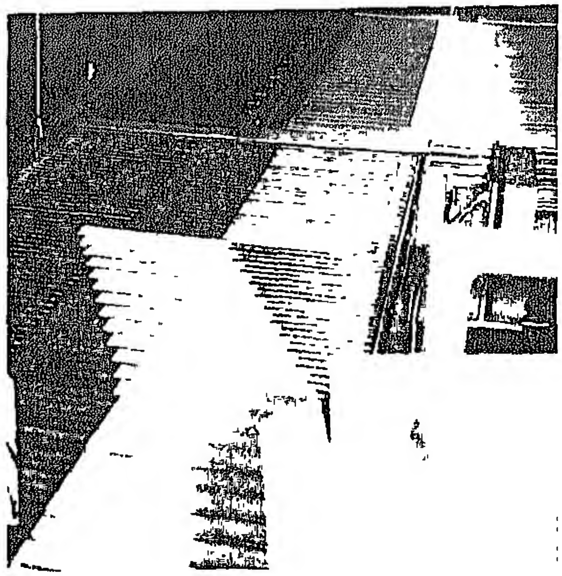

Figure 9.—Mechanical sorter.

trailers located at the dock. Reflective tape labels are placed on both sides of a tote box to indicate family groups or "slugs" of cases released from the selection line to the sorter. Once a reflector passes a photocell that conveyor is stopped and the next conveyor line begins to feed. The mechanical sorter interprets the "L," "O," or "X" markings and diverts these cases to the appropriate delivery trailer. The sorted cases are conveyed into the delivery trailer for loading (fig. 10).

Selection productivity for this system was as high or higher than any conventional grocery warehouse, primarily because of the batch-picking concept employed. A case selector can average 430 to 480 cases per man-hour, but only 285 cases per man-hour when manually and mechanically assisted selection operations, control station operators, and pallet load selectors are included.3/ However, receiving and put away and replenishment operations are similar to those of conventional warehouses.

Trailer loading productivity was 490 cases per man-hour, but the overall shipping pace which includes selection and loading dropped to 174 cases per man-hour.

3/ Assumed 250 cases per man-hour for manual and pallet load selectors.

Figure 10.—Truck loading.

Approximately $1 million were required to finance all of the materials handling equipment for this system. Included in this were $250,000 for order sorting equipment and $350,000 for conveyors, controls, installation, and related nonconventional mechanized equipment. Annual maintenance costs, including salary for two men, was estimated at $50,000 to $65,000.

The more significant advantages inherent in this mechanized order sorting operation are as follows:

1. High degree of control.

2. Order selectors in the mechanized selection area receive the same wages as manual employees.

3. The equipment installation time in a conventional warehouse takes only 5 months.

4. Flexibility has improved significantly over the manual order sorting operation.

In this grocery warehouse, inbound products are loaded onto pallets and placed in a backup position in flow racks directly behind the picking fronts. The products are placed in reserve storage if the two-pallet-deep picking slot is full when the products enter the warehouse.

Order selectors are transferred from slot to slot on a manually operated (fig. 11) picking platform. From the picking platform, order selection is

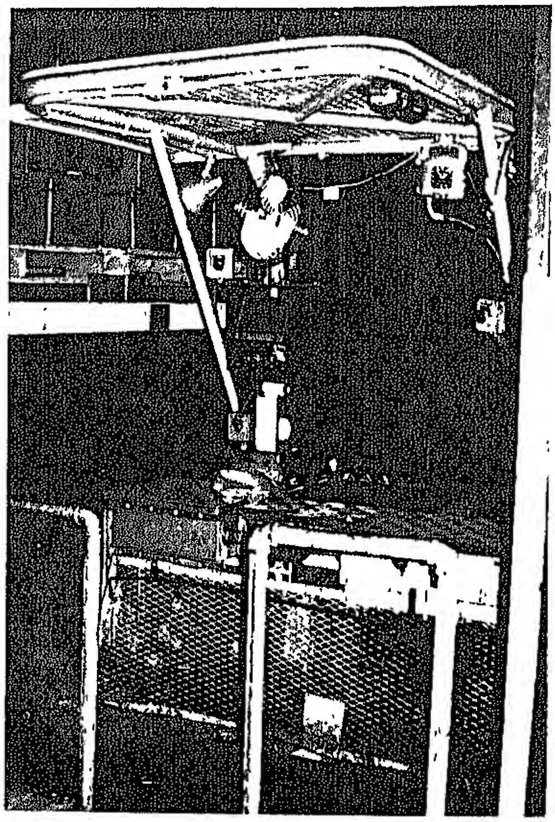

Figure 11.—Selection vehicle.

performed manually.4/ Each picking platform is assigned to two aisles and five levels of selection racks, which allows the selector to pick from both sides of the aisle each time the vehicle is stopped. The aisles used for order selection are 6 feet wide and have a monorail on the floor to guide the picking platform.

4/ This system should not be confused with multilevel selection operations for lower volume items (11).

A television-like viewer (fig. 12), which projects computer-prepared case labels from preprinted tape, is mounted on the vehicle. These computer-prepared labels are processed in selection-line sequence which permits a selector to batch-pick eight store orders from a given selection line. The selector advances the picking vehicle to the appropriate slot, picks the required cases, and places them on the vehicle's transfer table next to the viewer. The label is automatically applied to the case and the label for the next case then appears on the viewer.

An elevator-conveyor lifts the cases from the picking vehicle to a belt conveyor suspended from the ceiling of the warehouse. The belt conveyors merge to form a single line (fig. 13). The single line passes through an optical scanner and sorter where the data on the labels are scanned and the cases sorted. Once sorted, the cases are sent individually down roller conveyor lines (fig. 14) to designated stations (fig. 15) where they are manually stacked on pallets for each store. A worker can slide cases onto adjacent pallets with minimum effort because of the ball bearings imbedded in the tables. The pallets are set on scissor-jack platforms that are lowered as layers of cases are completed. Forklift trucks then load the full pallets on the appropriate delivery trucks.

The case selection operations in this mechanical transfer of selector represented an outstanding improvement compared with the manual and mechanical

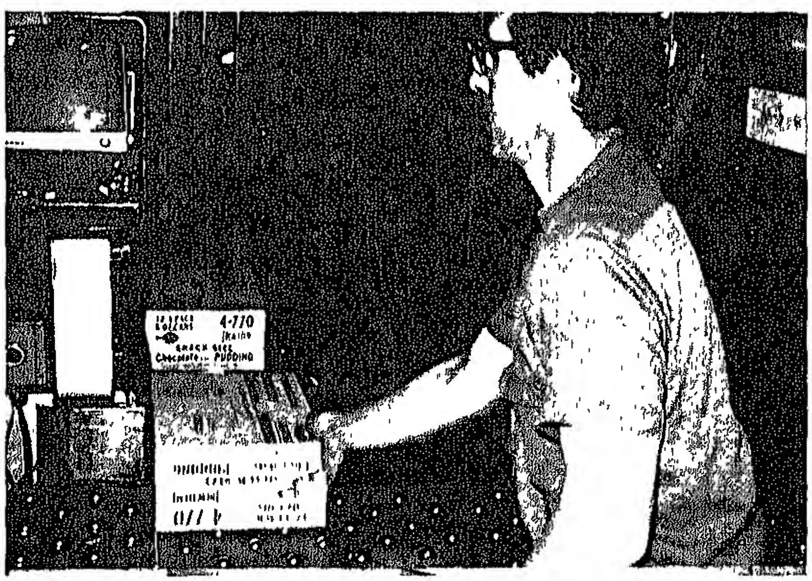

Figure 12.—Television-like viewer on selection vehicle.

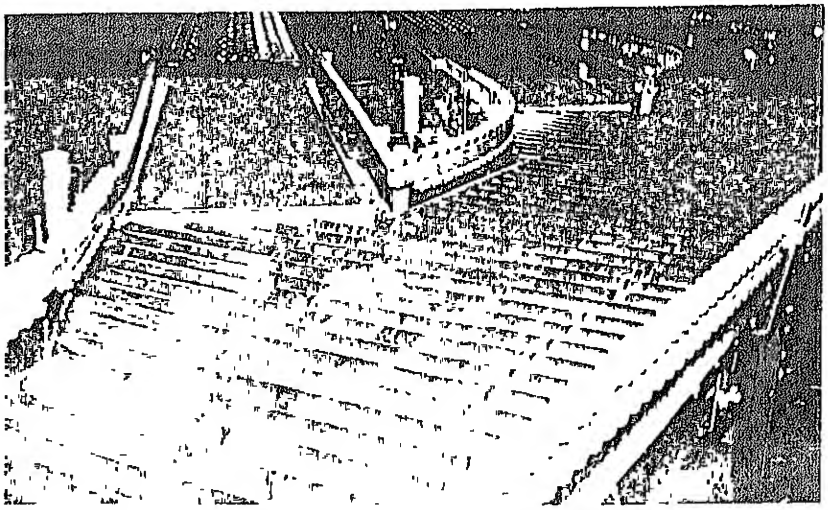

Figure 13.—Merging point for conveyors.

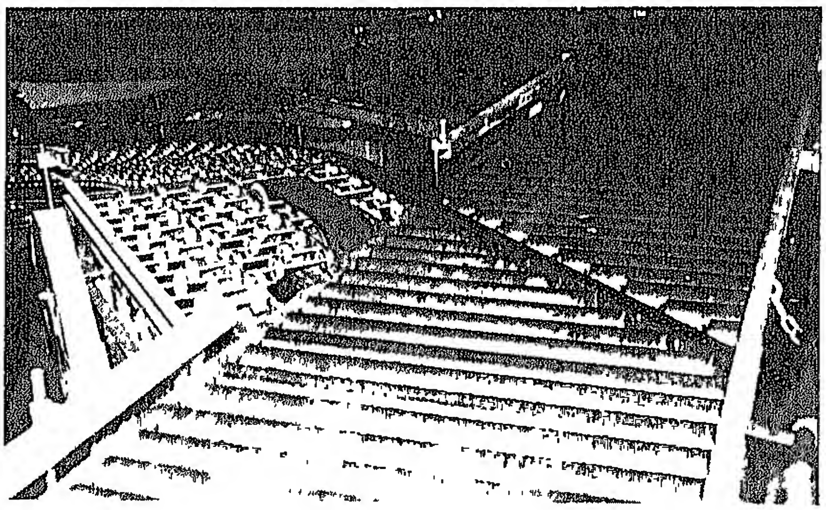

Figure 14.—Roller conveyor leading from sorting
to palletizing station.

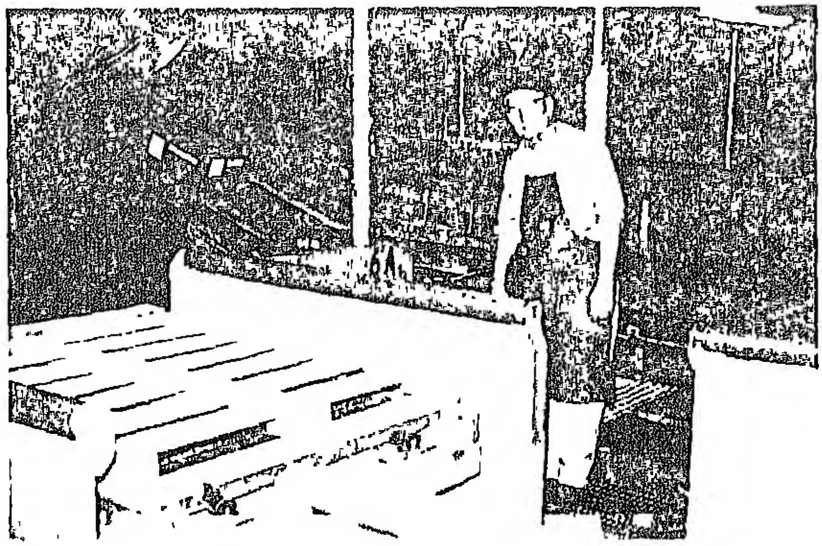

Figure 15.—Palletizing station.

order sorting operation. The receiving operation was similar, however, to most conventional warehouses. Productivity for the mechanically assisted case selectors averaged 525 cases per productive man-hour due primarily to the selection of eight store orders at one time.

Because the dock crew only handled unit loads of merchandise, trucks were loaded at a rate of 1,250 cases per man-hour. When manual palletizing at 450 cases per man-hour was included as part of the loading operation, the truck loading productivity amounted to 331 cases per man-hour.

Investment in the mechanized equipment for this operation was approximately $600,000. Costs of racks and other materials handling equipment were not included in this investment because these are also standard equipment in conventional warehouses. Maintenance for this operation amounted to $60,000 per year.

Advantages of the mechanized transfer of selector are as follows:

1. The preparation and application of the labels is a significant characteristic.

2. Similar skills exist for mechanized and manual selectors with minor differences in wages.

3. Case selectors work from five tiers of pallet racks (30 feet high) with remarkable safety records.

4. Installation of the system takes only 6 months.

5. Reliability improved considerably after debugging.

Unprotected glassware and bulky items cannot be handled in this operation and require a separate parallel picking system.

Mechanized Storage-Retrieval

The storage-retrieval operations are named after the general classification of machines used to perform these operations—storage-retrieval machines (S-R machines). The S-R machine, basically a cross between a forklift truck and a bridge-type stacker crane, looks like a stacker crane but moves on wheels like a truck. The machine is locked within an aisle and travels back and forth. It raises and lowers loads and moves the loads into and out of storage openings on either side of the aisle (3).

Unit Load Handling

In this nongrocery warehouse operation, forklift trucks transfer unit loads of products to and from the storage area on specially designed metal pallets. This 48-inch square captive pallet is required for the specific racks and transfer cars installed in the system, but the size of the pallet can be varied for other facilities.

When the unit load has been transported to the storage area, it is either loaded into one of the 18 load-unload stations or fed directly to the S-R machine if the machine is ready to handle a new load (fig. 16). The S-R

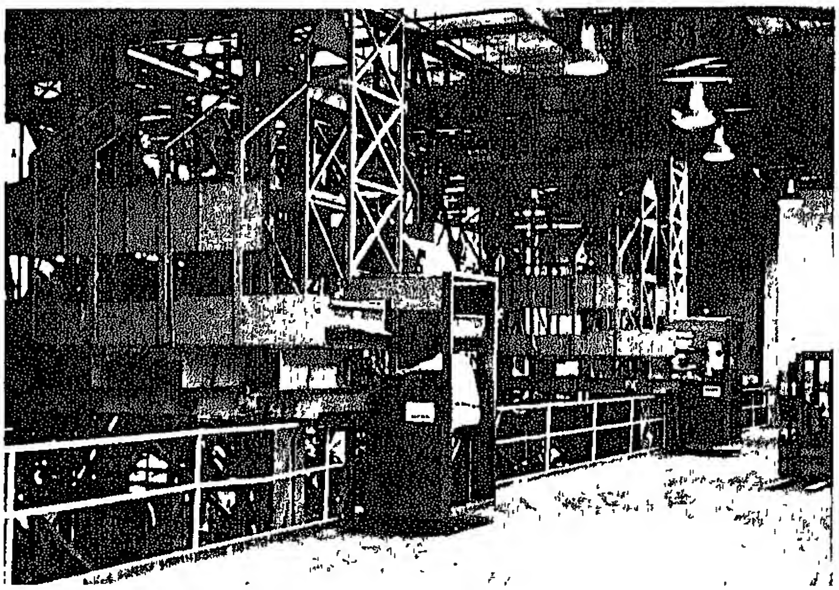

Figure 16.—Feeding and discharging lanes for storage-retrieval machines.

machine is programmed by its operator to put away the unit loads. A punch-card, containing the address of an empty storage location is inserted into the card reader in the operating console (fig. 17). The information on these

Figure 17.—Operating console for a storage-retrieval machine.

permanent cell or bin address cards is prepared by data processing. These same cards are used to program the S-R machine when unit loads in storage are required for the manufacturing operating.

The machine's transfer car receives the instructions and carries the load to the designated row where the S-R machine is dispatched with the unit load to the assigned storage cell (fig. 18). The S-R machines and the transfer car both operate on floor-mounted rails with overhead guides to

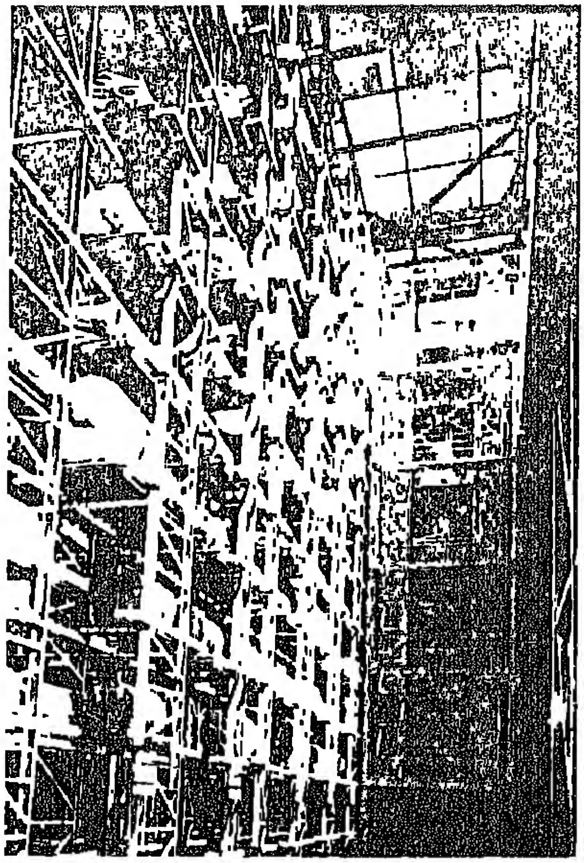

Figure 18.—Storage cells used with storage-retrieval machines.

maintain vehicle alinement (fig. 19). The storage row, column, and level are located by a magnetic sensor. A mechanical probe attached to the machine determines whether the cell is empty and electric eyes determine if the pallet is properly loaded.

To put away and retrieve a loaded pallet successfully, the racks and S-R machine must "match" very closely. A clearance of three-fourths inch on each side of the pallet lets the S-R machine find the opening in racks as high as 65 feet (12 tiers).

Before the unit load is put away, a transaction card containing the storage address and product identity is keypunched by the machine's operator. These cards are then sent to data processing for updating inventory records.

A $900,000 investment for this "12,000 storage cell" facility was made for the racks, two transfer cars, two S-R machines, track, and controls. Included in this figure was $225,000 for installation. In addition, 12,000 metal pallets at $40 each amounted to $480,000. At $25 per square foot, $1 million would be required to construct a building for this type of operation.

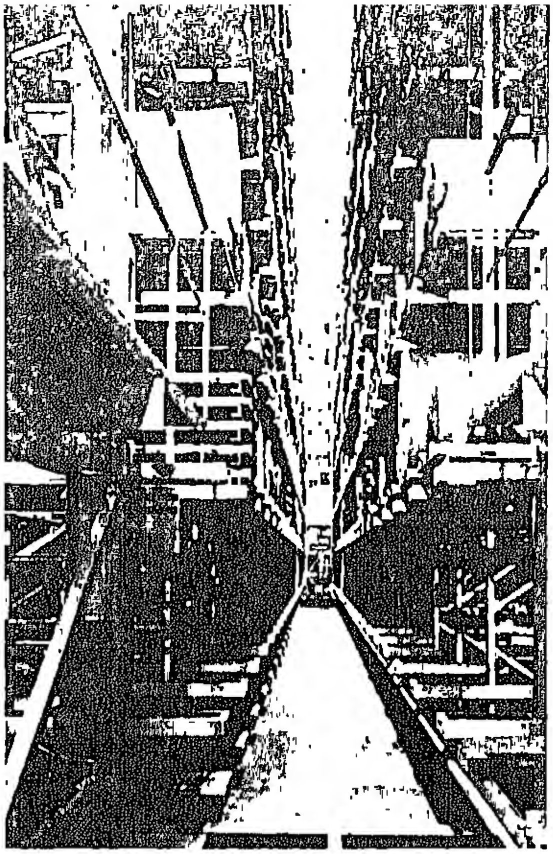

Figure 19.—Aisle and guide rail used for storage-retrieval machines.

On-the-job training for a machine operator takes 250 hours and he is paid 45 percent more than a forklift operator. The only maintenance required is primarily for preventive measures and averages about $6,000 per year. Electricians are available to serve the installation on each shift.

The throughput productivity to be obtained from this operation is primarily dependent upon the horizontal and vertical speeds of the machines. The S-R machine operates at 400 feet per minute horizontally and 90 feet per minute vertically. The transfer car operates at 60 feet per minute. With only one operator for the two S-R machines, the system performs at a rate of 300 transfers (stock put aways or retrievals or both). This would be equivalent to 300 tons or 21,000 cases (70 cases per ton x 300 tons) per 8 hours. With two operators (one for each machine), productivity increased to 480 transfers (480 tons or 33,600 cases per 8 hours). A forklift operator normally makes only 15 transfers per man-hour (120 transfers, 120 tons, or 8,400 cases per shift); therefore, four forklift trucks would be required on an 8-hour shift to perform 480 transfers.

Advantages of the unit load handling operation are:

1. The high level of operational control.

2. Excellent safety record because no personnel are allowed in the storage area.

3. The basic system can be modified for a variety of applications such as with pallet flow racks.

4. Outstanding reliability while operating three shifts a day.

Pallet Load Cycling

In this nongrocery warehouse operation inbound materials are placed on pallets and the fully loaded pallets are placed on 44- by 44-inch plywood "slabs." the plywood provides a uniformly sized base necessary for proper alinement and clearance when the pallet loads are put away or retrieved from the racks. Forklift trucks place the loaded pallets on live roller conveyors (fig. 20).

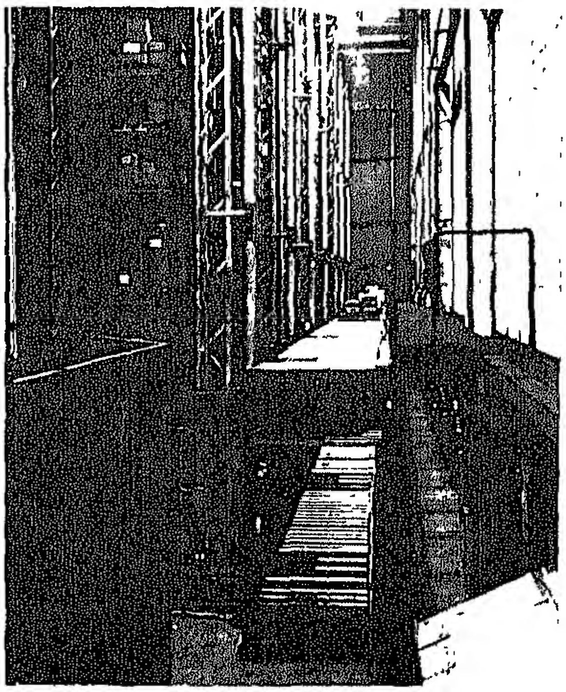

Figure 20.—A pallet load on a line roller conveyor.

The pallets pass through a series of electric eyes and load size indicators enabling the operator of the storage-retrieval machine to select a storage cell relative to the size of the loaded pallet. The electric eyes will also indicate whether a load is too large for the system. The operator

removes a copy of the merchandise receiving ticket from the load and selects a storage location punchcard corresponding to an available cell. Meanwhile, the S-R machine is programmed to place the load in storage. Together the punched card and receiving ticket are placed in a plastic envelope for filing and inventory updating.

From the data provided on the load's punched card, the console operator determines whether all or part of the pallet load will be needed for that particular order. If merchandise remains on the pallet, the card is placed in a "holding" rack and later restored. If all the cases are needed, the card is filed to be applied to new merchandise arrivals. The loaded pallets are then cycled through a manual piece picking (batch selection was used here) section where order selectors obtain the required cases and stack them on adjacent pallets (fig. 21). Forklift trucks subsequently take loaded

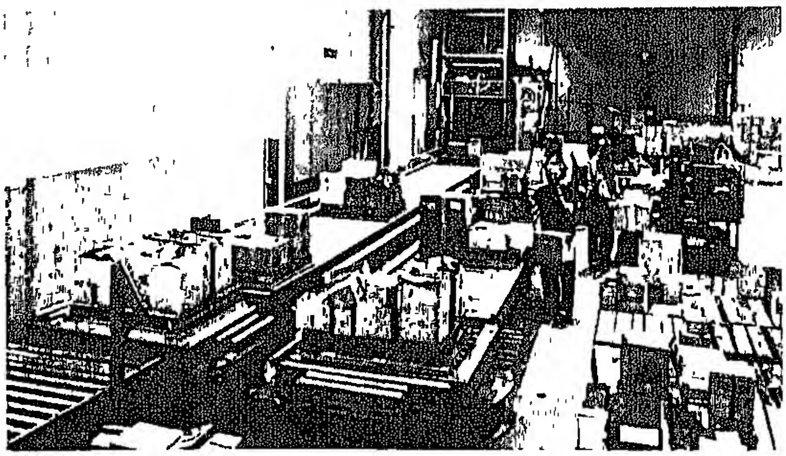

Figure 21.—Manual piece picking section through which pallet loads are cycled.

out-going pallet to the loading dock. If the manual selectors leave a pallet partly loaded, the partly loaded pallet is sent back to the console operator and recycled into storage. Because separate conveyors are used for retrieving and putting away pallet loads, a continuous flow of merchandise to and from storage is provided.

The S-R machine in this operation is capable of handling 800 transfers (equivalent to 800 tons or 56,000 cases of groceries) during a 16-hour work day. Consequently, an order selector picks from 400 pallet loads during that period. This nongrocery warehouse selects orders at a rate of 1.5 tons per man-hour, but in a typical day a grocery warehouse would at least triple that figure. Significantly this operation eliminates the need for selection-line storage and the stock replenishment that was necessary for the unit load handling. Furthermore, this S-R operation utilizes approximately 18,000

square feet compared with the 96,000 square feet needed for a three-level rack installation serviced by forklift trucks.

A $951,000 investment in this operation provides 5,840 storage cells, seven S-R units, conveyor feeds and take aways, an operating console, and 6,000 plywood slabs valued at $48,000. Annual maintenance costs would average about $20,000.

A significant advantage of this operation is the excellent control it provides over warehouse employees. All work is brought to the workers while they remain at their designated work stations.

Reserve Storage and Replenishment

In this nongrocery warehouse operation the merchandise received is loaded on pallets and placed on wood slab bases similar to those of the pallet cycling operation. Forklift trucks take the loaded pallets to the S-R machine's staging location and the machine places the pallet loads in storage. Gravity-fed racks allow the S-R machine and forklift trucks to operate independently at the staging station. The crane is programmed and controlled from a remote location where closed circuit television is used to communicate to the operator. The operator uses punched cards to instruct the machine. Up to seven operations can be preprogrammed.

The storage racks in this warehouse were designed so that as many as seven pallet loads can be stored in each machine aisle facing. Both storage and retrieval are performed at a single aisle facing. To do this, the machine pushes the previously stored loads further back into storage, thus providing the necessary space for the loads that are currently being stored. Storage racks may reach 45 feet in height with a row depth of seven pallets. Inventory turnover is performed by picking merchandise from a completed row while new arrivals are placed in a second row. Consequently, with the high product volume movement in this operation first-in, first-out storage exists at all times.

The order selection area located directly below the storage area is replenished by the S-R machine. Two-pallet deep gravity racks are used in the order selection area instead of seven-deep gravity racks as were used for storage.

At the time of our study, a new procedure for order selection was being installed in this warehouse while the older method was concurrently being phased out. In the older method, the order selector pushed a four-wheel cart through the picking area and picked one order at a time. Full carts were placed at the truck dock for delivery trailer loading. In the new method, a guided tow-tractor pulling a train of carts through the warehouse permits the order selector to pick up to five orders at a time (fig. 22). A hand-held control unit moves the train from slot to slot. Forklift trucks load the completed orders on the appropriate delivery trailer at the truck dock.

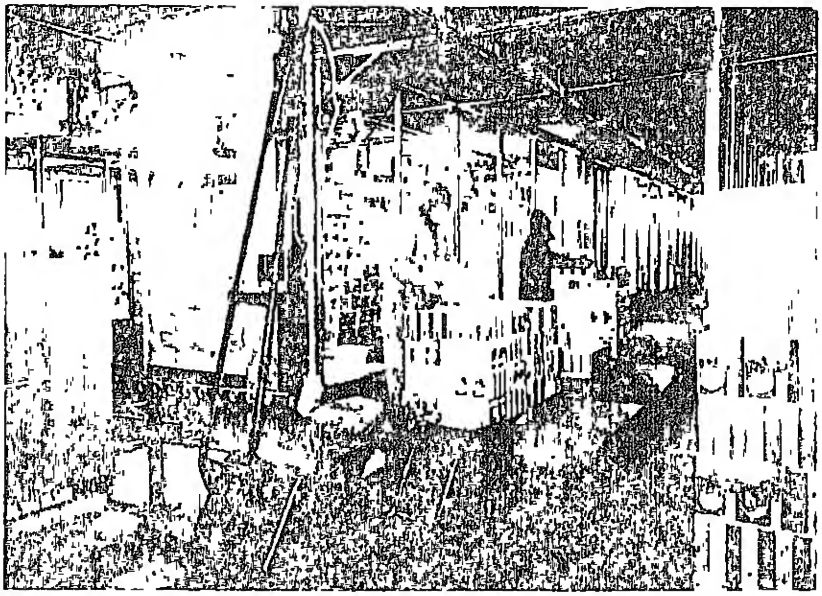

Figure 22.—Guided tractor train.

The productivity of this system is dependent upon the machine speeds and areas of application. The receiving functions can be performed at a rate of 11 tons (770 cases) per man-hour. The overall productivity for replenishment, order selection, and truck loading in the older method of selection was 125 cases per man-hour. If the replenishment function were treated as an inbound operation, the inbound pace would drop to 8 tons or 560 cases per man-hour. Overall productivity is expected to increase to 160 cases per man-hour with the new method of selection.

Approximately $194,000 was required to purchase and install the equipment in this system. The S-R machine and installation cost about $83,000; the racks, another $96,000; and the automatic tractor train, approximately $15,000, including installation. The building itself would cost approximately $22 per square foot. Maintenance (primarily preventive) costs average $2,400 annually.

One of the more noticeable advantages of this system is the wide usages of the S-R machine and the effective control it has on the warehouse. Even though the S-R machine connects the receiving, replenishing, and order selection operations it does not "machine pace" those operations.

Mechanized Selection

In this grocery warehouse operation, products are delivered by railcars and trucks. The shipment is unloaded by warehouse employees and truck drivers, placed on pallets, and transported to storage by forklift trucks. Through the use of a systematic numbering system, products were stored in

racks with each slot corresponding to the mechanized line. When necessary, pallet loads were transferred to a platform behind the appropriate chute on the mechanized line (fig. 23). Partial loads were removed from the platform and placed in storage slots beneath the platform.

Figure 23.—Forklift truck positioning pallet of products on platform of mechanized selection machine.

This mechanized operation consists of 10 levels of inclined chutes with each level having approximately 210 chutes capable of holding an average of 25 cases per chute (fig. 24). The chutes are filled from the rear on two levels by men stationed on the platform (fig. 25). Each man is responsible for five levels of 700 to 1,000 chutes depending upon daily replenishment demands.

Replenishing the chutes is scheduled by placing the next day's orders in the computer in the sequence in which they will be selected. The computer printout tells which chutes will need replenishment and at what time replenishment must be completed. The computer is programmed to call for replenishment when approximately 2 hours of supply remains in the chute.

Order selection is performed by inserting cards containing store information, item code, and quantity of items ordered into a computer (fig. 26). This information combined with information in its memory causes the computer's release mechanism (fig. 27) to open allowing one case to slide onto a conveyor. The conveyor moves the case to the point where it is merged with other cases in the same order (fig. 28).

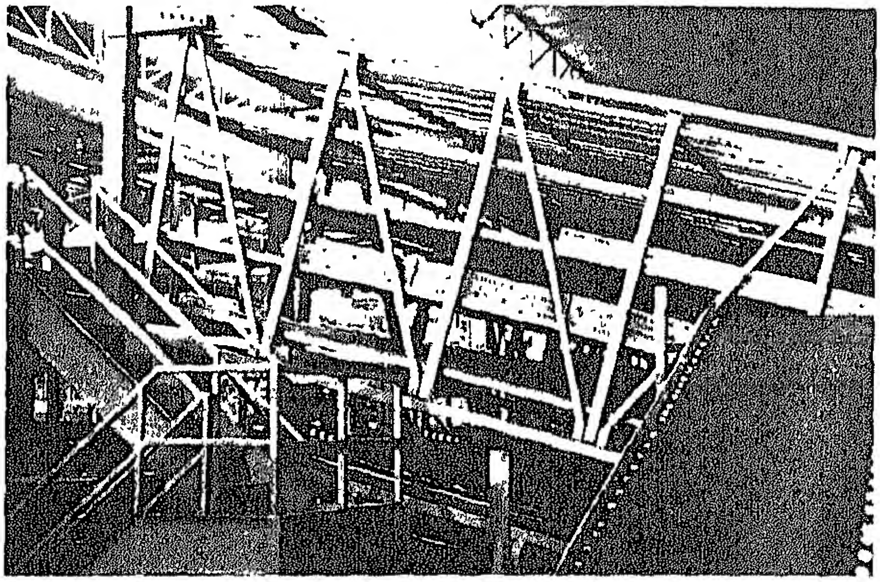

Figure 24.—Upper five levels of inclined chutes on selection machine.

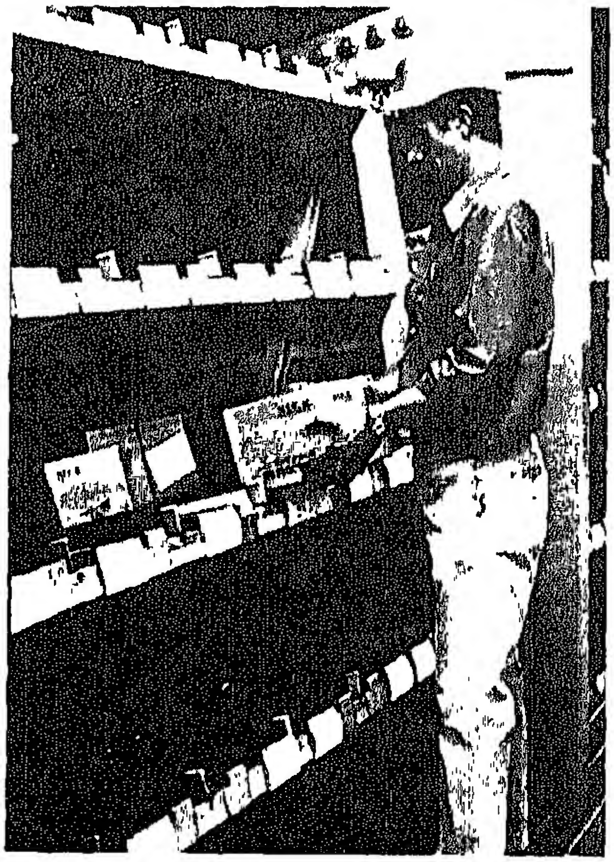

Figure 25.—Filling inclined chutes.

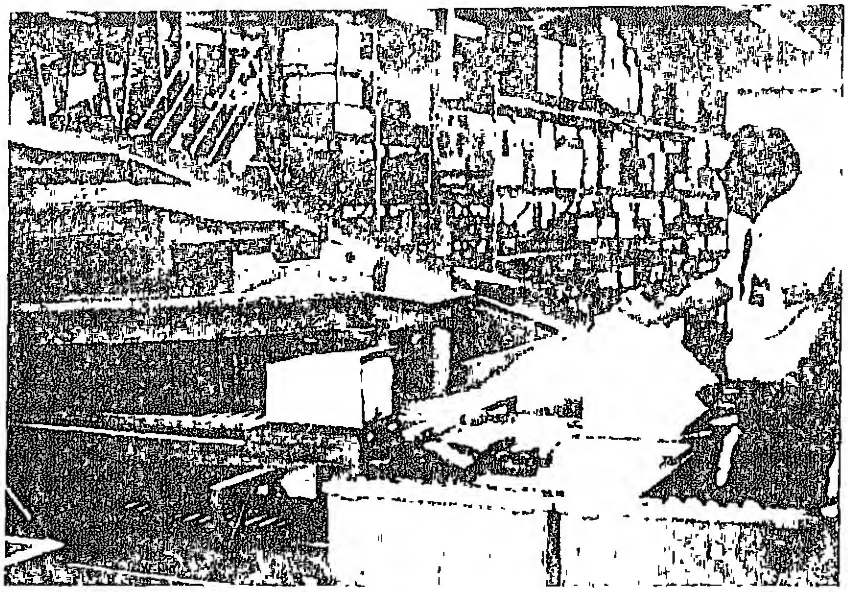

Figure 26.—Control point for mechanized selection, showing card reader (box on which man is resting his hand), closed circuit TV monitor showing loading dock, and manual overriding controls (immediate foreground).

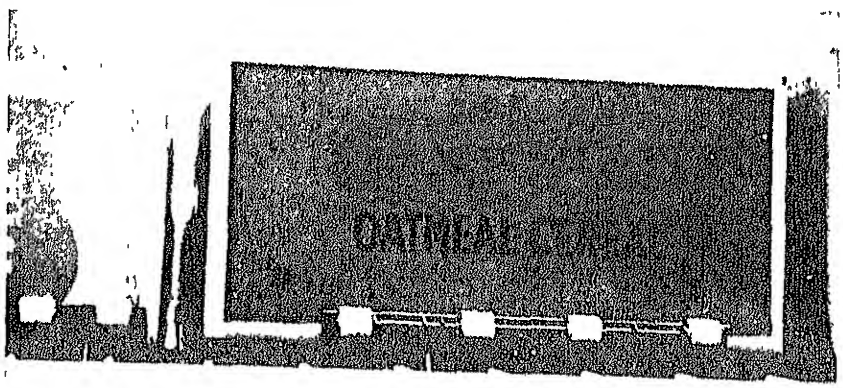

Figure 27.—Trip mechanism holding case in inclined chute.

The order selection sequence is as follows:

1. Thirty cases are selected for the first store at a rate of one case per second followed by a 4-second delay.

2. At the end of the 4-second delay, 30 cases are selected for the second store. This also is followed by a 4-second delay.

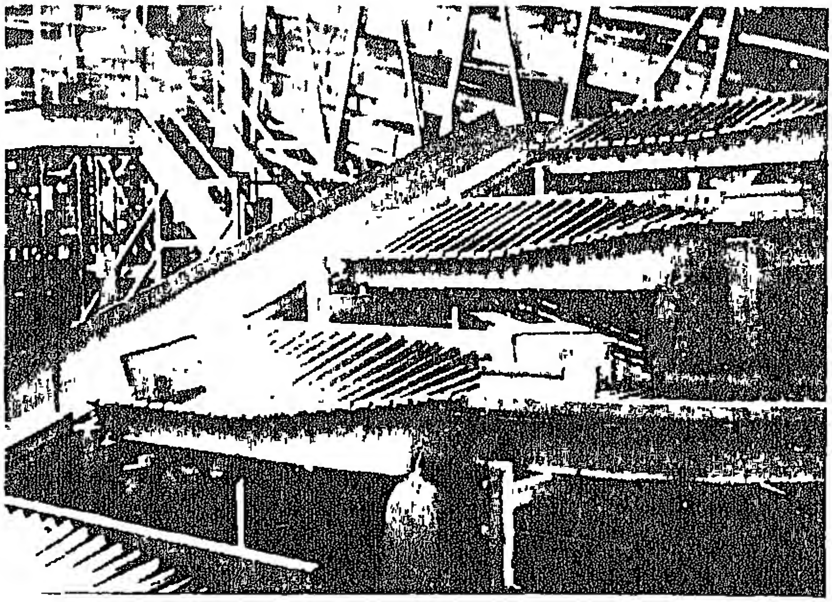

Figure 28.—Conveyors from selection level merging into one conveyor.

3. At the end of the 4-second delay, 30 cases are selected for the third store. A 4-second delay follows.

4. At the end of the 4-second delay, 30 cases are selected for the first store. The sequence continues until the orders for the three stores are completed, at which time selection of the next three store orders begins.

Mechanized order selection is performed at a rate of 635 cases per man-hour. (This figure is calculated as follows: 30 cases ÷ 30 seconds for selection + 4-second delay = 0.8824 cases per second. 3,600 seconds per hour x 0.8824 cases per second = 3,177 cases per hour. 3,177 cases per hour ÷ 5 men (4 men replenishing 5/ + 1 man at computer) = 635 cases per man-hour.) When manual order selection was included, overall order selection productivity amounted to 485 cases per man-hour (based on assumptions that manual order selection was required for 30 percent of the cases shipped and that manual order selection productivity was 250 cases per man-hour).

Cases already selected are moved on conveyors located in front of the chutes. The 10 conveyors on each side of the mechanized section merge into 2 conveyors on each side. These two conveyors subsequently merge into one conveyor on each side which transfers the cases to the diverter (fig. 29). The computer-controlled diverter separates the orders and routes them over one of three conveyors leading to the appropriate trailer of the loading dock.

5/ Replenishment labor was charged to selection because this type of replenishment was unique to this method of selection.

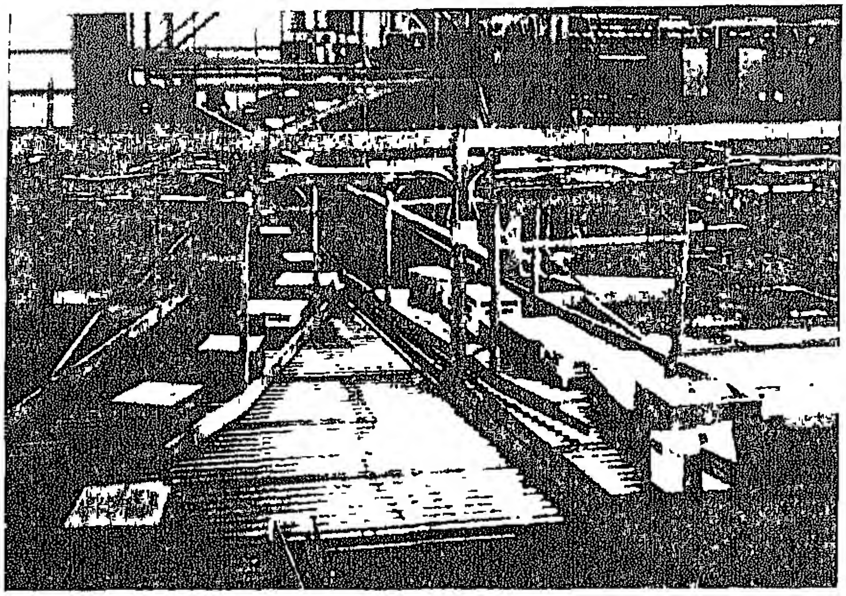

Figure 29.—Case diverter.

Two special sections located on each of the three conveyors leading to the trailer loading area provide a continuous flow of products for loading.

Before reaching the truck loading dock, cases move from the diverter to a 100-foot long accumulation conveyor. This conveyor stores and releases cases on demand without damaging any of the products. Cases are removed from the accumulating conveyor and released at a steady pace of approximately 25 cases per minute. As a result, a continuous product flow is maintained without sudden pileups or periodic time lags.

A telescoping conveyor extending into the truck is used for loading cases (fig. 30). Two men remove the cases from the conveyor and stack them directly on the floor of the truck or onto pallets already positioned in the truck. The conveyor is geared to deliver cases at a rate of approximately 25 cases per minute or 1,500 cases per hour (750 cases per man-hour). This rate is greater than the conveyor delivery rate, allowing sufficient time for relocating the conveyor laterally from truck to truck and for manually loading selected items while still keeping pace with the machine's picking rate. Adding in these additional elements decreases loading productivity to 667 cases per man-hour.

This particular mechanized operation was purchased as a package for approximately $1.5 million. A 116,500 square foot building with a stacking height of 27 feet was constructed at a cost of $1.6 million, including costs of heating, foundation, and a reinforced ceiling. Weekly power requirements, at the time of our study, amounted to $450. The estimated life of the system is 15 years. Annual maintenance costs amounted to approximately $18,000 including salary for two men.

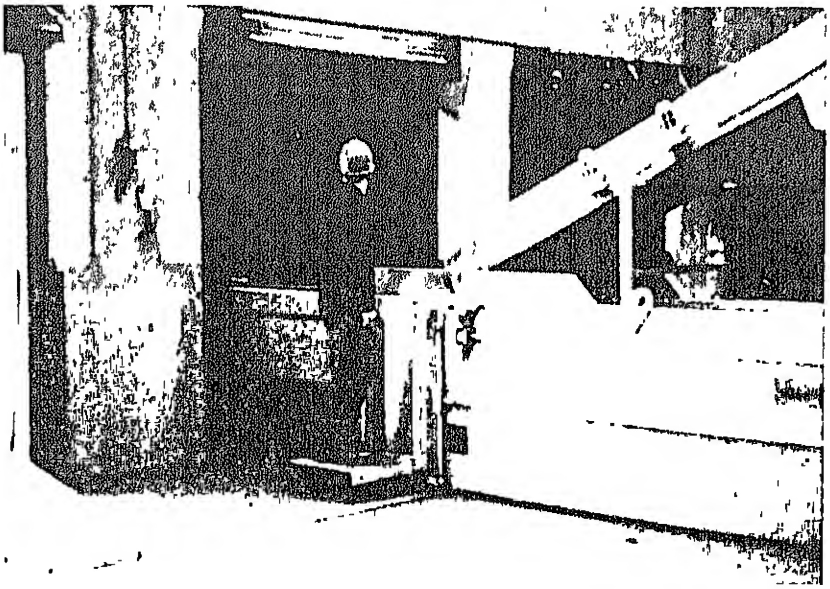

Figure 30.—Conveyor leading into delivery truck.

Bagged items, brooms, and mops, shrink packed items, items having less than 5-inch maximum case dimensions, repack items, and cases over 50 pounds cannot be handled in this operation.

At the time the study was being conducted the operation handled only the slow moving items which accounted for approximately 50 percent of their weekly shipping volume. Fast moving items were selected manually from a short selection line. This mechanized operation could, however, handle the fast moving items if two or more chutes were allocated for each item. Items shipped in pallet-load quantities, such as sale and promotion items, would still be handled by forklift trucks.

A computer breakdown in this completely computerized operation presents a potential problem because manual selection would be extremely difficult to accomplish. Loss of inventory records in the event of breakdown is not a serious matter since the inventory of the previous day is always kept on a punched tape.

This operation takes from 24 to 48 hours from the time an order is received until it is delivered. The items and quantities of orders initially received are marked with a pencil on special mark-sense cards. Complete mark-sense cards are placed in readers where orders are transmitted to the computer center. The orders are transmitted back to the warehouse by teletype and simultaneously punched on cards. These teletype documents become shipping documents and are sent to the proper store. The time between store ordering and delivering will be reduced with the new automatic telephone-tape system being installed in this warehouse.

Each day 1 hour of computer time is spent on updating the inventory and 1 1/2 hours for replenishing the order run.

Additional installations currently being planned for this mechanized selection operation include computer-controlled vehicles that transfer pallet loads of products from the receiving dock to the storage-retrieval machines. With these innovations, the system will be capable of placing pallet loads to an automatic depalletizer. The merchandise removed from the pallets will be transferred to chute loaders. Customers' orders subsequently will be placed on mobile carts, pallets, or stacked on the floor of the delivery truck. The system's manufacturer anticipates an order selection productivity of about 120 cases per minute from 17,200 chutes.

COMPARISON OF HYPOTHETICAL CONVENTIONAL AND MECHANIZED GROCERY WAREHOUSE OPERATIONS

To simplify the comparisons of the hypothetical conventional and mechanized grocery warehouse operations, two adjustments have been made. First, the mechanized operations have been grouped into the following types: (1) Mechanized case take away and sorting; (2) mechanized selector transfer; (3) storage-retrieval machines; and (4) mechanized selection. The operation using mechanized case take away and manual sorting was eliminated because of its low productivity and inapplicability to grocery warehouses. The operations using S-R machines were combined into one group because of their similarity. Second, adjustments were made in productivities and costs, where necessary, to reflect the handling of 24 million cases of groceries per year by each of the mechanized operations and the hypothetical conventional operation. Finally, 30 percent of the products in the mechanized operation was assumed to be handled with conventional methods.

Productivity Comparisons

Productivity data for the hypothetical conventional and the four types of mechanized grocery warehouse operations are shown in table 8.

Receiving productivity was the same for the conventional and three of the four types of mechanized warehouse operations. However, overall receiving productivity was approximately two times greater in the S-R mechanized operation than in the other operations. This greater receiving productivity was due to the machines' higher put away and replenish productivity (2,100 cases per man-hour compared with 639 cases per man-hour for the conventional operation). To achieve the higher productivity, order selection would have to be performed from the racks used with the storage-retrieval machine. Otherwise, products would have to be transferred to the selection area.

Except for the mechanized storage-retrieval machine operations, order selecting productivity was greater for the mechanized operations than for the hypothetical conventional operation. To facilitate the comparison, a productivity of 250 cases per man-hour for the manual selection of nonconveyable items (30 percent of total items) was assumed because the selection lines for these items were shorter than in conventional operations. Some of the nonconveyable items were selected in pallet-load quantities. The mechanized selection operation had the highest overall order selection productivity (485

TABLE 8.—Productivity for hypothetical conventional and mechanized grocery warehouse operations

Function	Hypothetical conventional 1/	Mechanized case take away and sorting	Mechanized selector transfer	Mechanized storage-retrieval machine	Mechanized selection
	Number of cases per man-hour				
Receiving:					
Rail unloading	462	462	462	462	462
Put away and replenish	639	639	639	2,100	639
Overall receiving	452	452	452	888	452
Order selection:					
Mechanized 2/	---	296	525	---	635
Manual	222	3/ 250	3/ 250	222	3/ 250
Overall order selection	222	285	430	222	485
Truck loading	1,584	4/ 667	5/ 331	1,584	4/ 667
Overall direct warehouse labor.	136	138	132	160	173
Indirect warehouse Labor 6/.	496	547	528	613	654
Throughput	107	110	106	127	137

1/ Average of conventional operations.

2/ Includes replenishment of mechanized area.

3/ Assumed 250 cases per man-hour because a short selection line could be used for individual cases and also some pallet load quantities were selected (approximately 30 percent of total).

4/ Since both operations used conveyors for loading the productivities were assumed to be equal.

5/ Palletizing included with loading.

6/ Does not include outbound order checking or data processing.

cases per man-hour) followed by mechanized selector transfer (430 cases per man-hour), mechanized case take away and sorting (285 cases per man-hour), and S-R machines and hypothetical conventional (222 cases per man-hour). The order selecting productivity for the S-R machines and the hypothetical conventional operations were identical because unless pallets were cycled or full pallet loads of each item were shipped, order selection would have to be performed conventionally where S-R machines were used.

Truck loading productivity was greatest for the S-R machines and hypothetical conventional operations (1,584 cases per man-hour) followed by the mechanized selection and mechanized case take away and sorting (667 cases per man-hour), and the mechanized selector transfer (331 cases per man-hour). None of the mechanized operations showed any increase in truck loading productivity. The higher productivity in truck loading in the hypothetical conventional operation resulted from loading mostly unitized (cart load or pallet load) products.

Overall direct warehouse labor productivity was greatest for the mechanized selection (173 cases per man-hour) followed by the S-R machine (160 cases per man-hour), the mechanized case take away and sorting type (138 cases per man-hour), the hypothetical conventional operation (136 cases per man-hour), and the mechanized selector transfer type (132 cases per man-hour). Three of the mechanized operations had greater overall direct warehouse labor productivity than the hypothetical conventional operation.

Indirect warehouse labor productivity in the mechanized selection operation was greater than in the other mechanized and hypothetical conventional operations. The indirect warehouse labor productivity data shown in table 8 do not include outbound order checking.

Throughput productivity is the measure of total warehouse productivity, excluding management. Throughput productivity was greatest for the mechanized selection operation (137 cases per man-hour), followed by the S-R machine operation (127 cases per man-hour), the mechanized case take away and sorting operation (110 cases per man-hour), the hypothetical conventional operation (107 cases per man-hour), and the mechanized selector transfer operation (106 cases per man-hour). All but one of the mechanized operations had greater throughput productivity than the conventional operation. However, productivity improvement does not tell the entire story. Labor costs also change with productivity changes, and equipment and warehouse costs change with the adoption of more highly mechanized operations.

Labor Cost Comparisons

As discussed in the section entitled "Productivity and Costs for a Hypothetical Conventional Grocery Warehouse Operation," labor wage rates were estimated to increase at a compounded annual rate of 8 percent. These labor wage rates for 1970 were reported as follows: (1) Power truck operators—$3.60 per hour; and (2) general materials handling labor (including inbound and outbound checkers)—$3.32 per hour. Applying the 8 percent increase, compounded annually, the projected wage rate for power truck operators in

1975 would be $5.29 per hour and for general materials handling people (including inbound and outbound checkers) would be $4.51 per hour. No estimation was made for supervisors' wage rates, but for comparison purposes a wage rate of $5.94 per hour was assumed for these employees. All operators of mechanized equipment were assumed to receive 15 percent higher per hour wage rates than the operators of conventional equipment.

Projected 1975 labor costs, based on 1,000 cases handled, for the hypothetical conventional and mechanized warehouse operations are shown in table 9. All but one of the mechanized operations have lower total warehouse labor costs than the hypothetical conventional operation. The mechanized selection operation had the lowest total warehouse labor costs ($44.07 per 1,000 cases) followed by the S-R machine operation ($44.87 per 1,000 cases), the mechanized case take away and sorting operation ($52.81 per 1,000 cases), the hypothetical conventional operation ($53.30 per 1,000 cases), and the mechanized selector transfer operation ($55.31 per 1,000 cases).

Equipment, Maintenance, and Facility Cost Comparisons

Equipment, maintenance, and facility costs for the mechanized warehouse operations are discussed below. How much extra cost resulting from the installation and use of advanced mechanized operations must be incurred to achieve the increased productivity and reduced warehouse labor costs (tables 8 and 9).

All cost estimates discussed below are based on original costs reported by the firms cooperating in this study.

Equipment Costs

Equipment costs for each type of mechanized operations include costs for conveyors, sorters, selector transfer vehicles, S-R machines, and mechanized selection equipment.

Mechanized case take away and sorting.—For the mechanized case take away and sorting operation, the cost of mechanized equipment included the cost of sorting equipment and the cost for conveyors, controls, installations, and other related equipment. Initial equipment costs for sorting amounted to $250,000, including installation, and the order selection initial equipment costs amounted to $350,000 for a total of $600,000. Assuming an 8-percent average annual increase, the total cost for this equipment would amount to an estimated $881,600 in 1975. The estimated life for this equipment, according to the cooperator, is 10 years. A 9-percent-interest rate was assumed and the total equipment cost was amortized over 10 years. The annual equipment costs amounted to $136,868.

Mechanized selector transfer.—The initial equipment costs for the mechanized selector transfer operation amounted to $600,000 which is the same as for the mechanized case take away and sorting operation and would

TABLE 9.—Projected 1975 labor costs for hypothetical conventional and mechanized warehouse operations

Function	Hypothetical conventional	Mechanized case take away and sorting	Mechanized selector transfer	Mechanized storage-retrieval machine	Mechanized selection
	-----Dollars per 1,000 cases-----				
Receiving:					
Rail unloading----------	9.76	9.76	9.76	9.76	9.76
Put away and replenish--	8.27	8.27	8.27	2.16	8.27
Overall receiving-------	18.03	18.03	18.03	11.92	18.03
Order selection:					
Mechanized--------------	---	12.99	7.31	---	6.04
Manual------------------	20.32	3.61	3.61	20.32	3.61
Overall order selection-	20.32	16.60	10.92	20.32	9.65
Truck loading-----------	2.85	7.22	15.00	2.85	7.22
Overall direct warehouse labor.	41.20	41.85	43.95	35.09	34.90
Indirect warehouse labor--	12.10	10.96	11.36	9.78	9.17
Total warehouse labor-----	53.30	52.81	55.31	44.87	44.07

amount to an estimated $881,600 in 1975. Assuming the same 9-percent-interest rate and amortizing the estimated total initial cost of the equipment over 15 years, the annual equipment costs for the mechanized selector transfer operation would amount to $109,538.

Storage-retrieval machines.—The average equipment cost per storage cell for the storage-retrieval machine operations amounted to $140 for storage-retrieval machines, racks, captive pallets, controls, and installation. Assuming an 8-percent average annual increase, the total cost for this equipment would amount to $205 per storage cell in 1975. According to some industry leaders, approximately 17,000 storage cells would be required for a grocery installation. Assuming 17,000 cells, the estimated initial cost of the equipment would amount to $3,485,000. Assuming an interest rate of 9 percent and amortizing the total initial cost of the equipment over 15 years, the annual cost of the equipment for the storage-retrieval machine operation would amount to $433,011.

Mechanized selection.—The equipment cost for the mechanized selection operation studied amounted to $1,500,000. However, to have the capability to handle the throughput equivalent to other operations studied, equipment costing $2,500,000 would be required. Assuming an 8-percent-average annual increase, the total cost for this equipment would amount to $3,675,000 in 1975. Amortizing the total equipment cost over 15 years at an interest rate of 9 percent, the annual equipment cost for mechanized selection would amount to $456,618.

Maintenance Costs

Maintenance costs reported by the cooperators included salaries of maintenance poeple and cost of parts required to maintain the mechanized equipment. The maintenance costs did not include any costs for maintaining conventional equipment.

Annual maintenance costs (including salaries and parts) for the mechanized case take away and sorting and for the mechanized selector transfer operations are estimated to amount to $80,000 each in 1975. Estimated annual maintenance costs for the storage-retrieval machine operations average $20,000 and include the salary of one man. Estimated annual maintenance costs average $25,000 and include the salary of one man, for the mechanized selection operation.

Facility Costs

Facility costs for the mechanized case take away and sorting, the mechanized selector transfer, and the mechanized selection operations would be the same as for hypothetical conventional operations. The mechanized operations occupied the same warehouse space in the firms studied as a hypothetical conventional operation would have occupied.

Facility costs for the S-R machine operations would be less than the facility costs for the hypothetical conventional operations because of greater storage heights possible with the S-R machines. As discussed in the equipment cost section, an estimated 17,000 storage cells would be required in a grocery warehouse using S-R machines.

In one very sophisticated grocery warehouse operation, the S-R machine operation has approximately 17,000 storage cells, and occupies 54,000 square feet of the warehouse. Clear stacking height in the S-R machine part of the warehouse is 68 feet. However, in order to perform conventional order selection in the S-R machine area, approximately 28,800 additional square feet of space or 82,800 total square feet would be required for selection aisles and slots. The clear stacking height of the S-R machine areas would also have to be increased by 8 feet. At the cost of $35 per square foot, to construct the facility for the S-R machine operation would cost $2,898,000 (82,800 square feet x $35).

Approximately 164,305 square feet of hypothetical conventional warehouse space (21 feet stacking, 11.5 feet aisle width with 67 percent of pallets used being 40 by 32 inches, and 33 percent, 48 by 40 inches) would be required to accommodate the products stored in the 17,000 storage cells plus selection slots for approximately 3,000 items (assuming one selection slot per item). Assuming that it costs 50 percent less per square foot to construct the hypothetical conventional warehouse than it costs to construct the storage-retrieval warehouse (3) total construction costs for the hypothetical conventional warehouse would be $3,833,234 (165,305 square feet x $23.33 per square foot), or $935,234 (32 percent) more than for the storage-retrieval warehouse.

Assuming an interest rate of 9 percent and amortizing the cost of both facilities over 30 years, the annual cost for storage-retrieval operation would amount to $278,208 and for the hypothetical conventional operation would amount to $367,990, a difference of $89,782 in favor of the storage-retrieval machine operations.

Total Annual Nonconventional Equipment, Maintenance, and Facility Costs

Projected 1975 total annual nonconventional equipment, maintenance, and facility costs discussed above are shown in table 10. To obtain the higher labor productivities (table 8) and the lower labor costs (table 9) management invested additional amounts discussed above and shown in table 10.

The total annual equipment, maintenance, and facility costs for the advanced mechanized operations per 1,000 cases shipped are also shown. The costs per 1,000 cases shipped should be used cautiously because any increase or decrease in volume would have an impact on these costs.

TABLE 10.—Projected 1975 total annual nonconventional costs for equipment, maintenance, and facility for four types of mechanized warehouse operations

Cost	Mechanized case take away and sorting	Mechanized selector transfer	Mechanized storage-retrieval machine	Mechanized selection
	Dollars per year			
Equipment	136,868	109,538	433,011	456,618
Maintenance	80,000	80,000	20,000	25,000
Facility	---	---	(89,782)	---
Total	216,868	189,538	363,229	481,618
Cost per 1,000 cases 1/.	9.04	7.90	15.13	20.06

1/ Based on potential annual throughput of 24 million cases.

Total Cost Comparisons

The total annual labor costs and added equipment, maintenance, and facilities costs for advanced mechanized operations are compared with hypothetical conventional operations in table 11.

As shown in table 11, none of the mechanized operations had lower costs than the hypothetical conventional operation. However, the total costs only show what happens in 1975. A more meaningful analysis must include estimated payback and return on investment.

Payback and Return On Investment

A popular approach to evaluating investment alternatives is the "payback" approach. The payback approach involves dividing net investment by the average net cash flow to determine the number of years required for a project to pay for itself. A more meaningful, although more time consuming, approach to evaluating investment alternatives is to estimate the return on investment for nonconventional equipment in each mechanized operation.

Using the hypothetical conventional warehouse operation as the base, a comparison of payback periods and returns on investment were developed for two of the mechanized operations (table 12). The mechanized case take away and sorting and the mechanized selector transfer operation were not included in payback and return on investment analysis because very little or no labor cost savings were shown for these operations relative to the hypothetical conventional operation (table 9).

TABLE 11.—Projected 1975 comparison of annual labor and added equipment, maintenance, and facility costs for advanced mechanized operations and hypothetical conventional operations

Cost	Hypothetical conventional operations	Mechanized case take away and sorting	Mechanized selector transfer	Mechanized storage-retrieval machine	Mechanized selector
	Dollars per 1,000 cases				
Warehouse labor 1/	53.30	52.81	55.31	44.87	44.07
Equipment, maintenance, and facilities 2/.	---	9.04	7.90	15.13	20.06
Total	53.30	61.85	63.21	60.00	64.13
Difference from conventional operations.	---	8.55	9.91	6.70	10.83

1/ Table 9.
2/ Table 10.

TABLE 12.—Estimated payback and return on investment comparisons for two types of mechanized warehouse operations 1/

Item	Mechanized storage-retrieval machine	Mechanized selection
Payback----------------------------years	9.5	11.7
Return on investment-------------percent	7.5	3.0

1/ Data based on investment in nonconventional equipment and labor savings of mechanized operations over a hypothetical conventional warehouse operation.

CONCLUSIONS

The advanced mechanized warehouse operations were not a good investment when compared with a hypothetical conventional grocery warehouse operation. This statement should not be interpreted to mean that advanced mechanized warehouse operations are not a good investment compared with any conventional grocery warehouse operation. Rather, the statement should be interpreted to mean that operators of grocery warehouses should attempt to improve their conventional operations before investing in highly mechanized equipment.

The only way to determine whether improving conventional operations or adopting advanced mechanized operations is the best investment is to conduct a feasibility analysis.

RECOMMENDATIONS

Based on the results of this study, the recommendations for future consideration are: (1) Seek ways to improve conventional grocery warehouse operations and (2) conduct a detailed feasibility analysis to determine whether improving conventional operations or adopting advanced mechanized operations is the better investment.

Ways to Improve Conventional Warehouse Operations

There are many alternatives for seeking ways to improve existing operations as follows:

1. Consult literature containing results of research conducted to improve warehouse operations, see "Literature Cited" at the end of this publication.

2. Hire a consultant who is specifically engaged in the business of improving warehouse operations.

3. Discuss operations with other warehousemen in an atmosphere of free exchange.

4. Review operating data from similar operations. (Caution should be exercised when this alternative is used because a slight difference in operations may cause a large difference in operating data.)

5. Use a combination of the preceding four alternatives—research results, consultants, discussion with other warehousemen, and operating data from similar operations.

Feasibility Study

There are 11 essential steps in the feasibility evaluation process. It is critically important that each step be completed before the next step. Although these steps have been developed in terms of their application to mechanized warehouse operations, they obviously also have application to any warehousing equipment or layout change.

Step 1, review of present conditions.—Review the present status of the warehouse and related operations in order to establish a base for comparison of alternatives. The following are recommended:

Determine whether the present productivity levels are as high as can be reasonably expected. Productivity levels are not only a function of how well employees work but are also influenced by motivation, methods, dispatching procedures, and layouts.

Review the utilization of available storage space to determine whether or not more products can be stored and handled. Cube utilization, row depths, aisle widths and locations, and storage of obsolete items can influence space utilization.

Study the effectiveness of present inventory control and stock locator systems and of buying policies and controls on warehousing.

Check the effectiveness of stock status reporting systems.

Explore the possibilities for expanding present facilities if additional space is needed in the foreseeable future. If land is available at the present site and if the long term warehouse plan included future expansion, expanding present facilities may offer a lower cost alternative for handling increased volume than installation of advanced mechanization system.

Determine the advantages or disadvantages of the present location and alternative sites. Some of the factors for consideration for the impact of changing warehousing locations are as follows:

1. The cost of store deliveries.

2. Inbound freight costs.

3. Availability and cost of land.

4. Availability and reliability of labor.

Step 2, return on investment goals.—Management should establish realistic return on investment goals for its use of capital. The same goal should be applied to similar types of capital expenditures. Management must bear in mind, however, that duplicating existing equipment and methods in a new facility will not automatically result in the same return on investment as in the old facility.

Step 3, future plans.—Future plans should be developed for the market to be served from the warehouse. These plans should include consideration of the following:

1. The number and size of stores and the extent of the geographic area to be served.

2. Potential increases or decreases in the number of items to be distributed.

3. Revisions in the methods of store deliveries, including plans for direct deliveries by vendors.

The planning should be performed so that future warehouse throughput in terms of volume and number of items can be projected.

Step 4, operational requirements.—Determine the operational requirements for the future. The operations should be defined in terms of "volume, number and type of items, order profiles, inventory turnover, service requirements, and cyclical variations." One of the first questions to be answered is whether or not present warehouse capacity is limiting and, thus, restrictive of growth and profits.

A growth pattern should be predicted and facility and equipment requirements planned to meet needs at least 5 years into the future.

Step 5, preliminary evaluations.—Make preliminary evaluations of where the greatest gains from an advanced mechanized warehouse can be made. This step can then serve to simplify subsequent selection steps by eliminating impractical or uneconomical alternatives. Preliminary evaluation should answer the following questions:

1. Using the basis established in the review of present conditions, where do the greatest opportunities for increased productivity exist?

a. In the receive and storage cycle?

b. In the selection and shipping cycle?

c. In providing more space?

2. If the analysis in step one shows there are benefits from considering another location -

a. Is land available?

b. Is a sufficient quantity of reliable labor available?

c. How will delivery and distribution costs be affected?

Step 6, list available equipment.—The available equipment should be cataloged. The cataloging should include not only equipment currently on the market but near-future developments which can be realistically expected. The equipment should not necessarily be limited to what has been used in the dry grocery field. Equipment trends in other industries should also be recognized. The cataloging should include information about the equipment specifications, costs, productivities, and reliabilities.

Step 7, update cost trends.—Review the trends of labor, equipment, and construction costs to ascertain if there are any significant changes or local differences.

Step 8, select alternatives.—Select those alternatives that appear to be most applicable on the basis of the greatest potential gains as determined in the fifth step (preliminary evaluations) and the listing of equipment as performed in the sixth step (list of available equipment).

The selection of alternatives may very well cover a wide range of possibilities. At one extreme could be the alternatives of improving or expanding the present warehouse system and facility or both. The other extreme might be full mechanization of all warehouse functions. Between these two extremes might be partial mechanization or mechanical aids to manual functions, such as conveyors and sorting equipment to supplement manual picking, or automating some items and using conventional methods for the remaining stock.

Step 9, test alternatives.—This step involves testing the alternatives selected in step 8 through the use of general criteria. The criteria would be similar to the return on investment analysis. Updated and localized cost trends and specific assumptions applicable to the specific company should be incorporated. As a result of the testing, only those alternatives which meet company objectives should be given more detailed analysis.

Step 10, simulate operations.—The operations of the alternative systems selected in step 9 should then be simulated on paper by applying the criteria to various workload profits. This simulation will verify if and how operational requirements can be met by various equipment configurations.

The purpose of the simulation is to synthesize on paper of alternative systems under the required conditions for sufficient periods of time to cover the variation in demands that will be placed on the system. Inputs to the model would include the operational requirements developed in the fourth step and the equipment capabilities. The equipment capabilities should include equipment speeds, capacities, and labor requirements.

The simulation outputs will include equipment requirements, investment, and operating costs. With this output the savings and return on investment can be calculated.

Step 11, make decision.—Based on the findings resulting from the simulation of operations, it should be possible to make a decision as to which system is preferred. Some objective judgments should become part of the decision-process, including:

1. Expectation of early technological obsolescence.

2. Flexibility of systems to meet trends.

3. Other intangibles, such as availability of capital.

THE 1980 PROTOTYPE

Companies whose conditions can justify the expenditures can look forward to a mechanized dry grocery warehouse in 1980 with the characteristics presented in the following paragraphs.

System and building design.—The building in which this model food distribution warehouse will be housed will be 80 to 95 feet high, thus minimizing building construction and land costs.

The rail and truck receiving will be performed in a manner similar to the present procedures with unitized loads being moved from vehicles into the system primarily by forklift trucks. A much greater percentage of materials will be received in unitized loads.

S-R machines will be used for moving inbound materials to storage and putting them away. There will be some segregation of products in the storage racks so that movement between storage and selection can be minimized. However, within assigned areas there will be complete flexibility to avoid fixed slots for specific products.

There will be a mixture of multidepth and single depth storage racks to accommodate items moving in different volumes.

There will be total computer control of the storage system from point of entry to assignment of storage and selection locations. The computer locator and operating control system will be tied into the company's total information system.

Automated transfer from unitized loads retrieved from the storage racks to the positioning of individual pieces for order selection will be possible.

Individual piece selection will be performed by a computer which will release picked cases onto conveyors leading to sorting and shipping. A number of store orders will be batched. The number of store orders selected concurrently will have minimal limitation and can be set for the number which best satisfies store service, delivery fleet, and warehouse requirements.

The chutes or slides for each product will be long enough to more nearly accommodate a full pallet of merchandise, thereby eliminating the need for recycling partly full pallets.

More than one item at a time will be released from storage. This will be possible because of the sorting system which will have the capability of "keeping score" of the numbers of each item necessary for each store order and directing them to the proper delivery shunt. The reader will transmit this to the computer regardless of the mix of items passing it.

There will be accumulation lines in front of each vehicle at the loading dock in order to level out the loading workload. The loading for stores will be performed manually off extendoveyers onto carts or onto pallets located in the vehicles. Such an operation would mean the products would practically never be handled manually except at the start of the cycle (receiving) and at the end (loading).

Throughput performance.—There would be no top limit to the throughput capability of the described operation. The operation could be designed to handle various combinations of items and input and output requirements.

As an example, let us assume that orders for nine stores were to be selected and loaded at one time. Also, let us assume that the output would be scheduled at the rate of 750 cases per hour per vehicle loaded. This would mean a throughput of 6,750 cases per hour or 108,000 cases in 16 hours. The selection of 6,750 cases per hour would probably be performed by two line items being released concurrently. If other than nine stores should be handled at one time, the system could be planned accordingly. If this same example were extended to the input end, it would mean that 6,750 cases or approximately 135 pallets per hour would have to be brought into the system.

At a cycle time of slightly under 2 minutes, four S-R machines could handle this load. The equivalent of another four S-R machines would be required for transfer from storage to selection. There would be staging capabilities preceding the input to the storage system to provide for full utilization of the S-R machines. More than one unitized load possibly could be put away in one cycle.

Therefore, it is estimated that required throughput will not place any restrictions on the model operation. However, projecting throughput requirements will be extremely important in planning the total operation and its components.

Conclusions.—The development of equipment with the 1980 prototype's operating characteristics is dependent upon technological advances and the success of installations which will be made in the years preceding 1980. The ultimate achievement of the prototype selection operation is heavily based on the assumption that a mechanically and economically feasible transfer system from unitized storage loads to individual selected pieces will be developed. If this assumption does not materialize, the selection portion of the projection would be subject to modification.

ADVANCED MECHANIZED GROCERY WAREHOUSE OPERATIONS INSTALLED SINCE THIS STUDY

Since the time this study was conducted, a few grocery warehouse operations that are more highly mechanized have been developed. These more highly mechanized operations were not included because they were not fully operating while the study was being conducted and because the firms having them were not ready to have their operations reviewed in great detail. However, to round out this study, the more highly mechanized operations are briefly described. There have been slight modifications in equipment but no other major developments.

One of the more highly mechanized operations now in use is similar to the mechanized case take away and sorting operation. However, with the more highly mechanized operation up to 15 store orders are batch-selected as compared with 3. The cases are sorted mechanically and conveyed to the proper delivery vehicle.

A second more highly mechanized operation combines the mechanized case take away and sorting operation with the storage-retrieval operation. Products are placed into reserve storage and selection slots are replenished by storage-retrieval machines. Order selection is performed from three levels (floor plus two mezzanine) as compared with two in the operation used in this study. This operation takes advantage of greater storage density and height offered by the storage-retrieval machine and the additional level of order selection.

A third more highly mechanized operation combines the mechanized selector transfer and the storage-retrieval operations. In one of these operations, products are placed in racks that are 11 pallet levels (or cells) high. The top five levels are used for reserve storage and the bottom six levels are used for order picking. Eight store orders are batch-selected.

A final more highly mechanized operation is one combining the mechanized selection and the storage-retrieval operations. This operation combines the two more productive operations evaluated for this study. One of these

operations has in excess of 17,000 storage cells and has more than 3,000 items in 5,000 lanes of the selection machine. Pallet loads of products are removed from storage and mechanically transferred to depalletizing stations. Products are manually depalletized and mechanically conveyed to the man loading the lane in the selection machine. The correct quantity of products transferred from a pallet to the selection machine as well as the correct time to transfer the product are determined by a computer. This operation is almost entirely computer-controlled.

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